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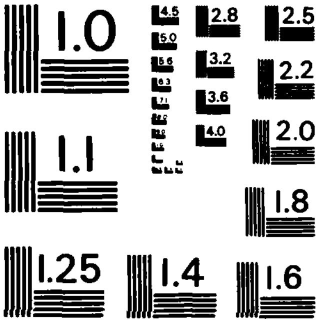
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Database Design for Structural Analysis and Design Optimization

By

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This report presents a procedure for design of database for structural analysis and design optimization. The procedure involves three distinct steps: (i) collection of information, (ii) analysis of data flow and (iii) identification of relations and data sets. The procedure is used to design a database for analysis and design of systems for linear, nonlinear, static and dynamic responses. Databases of two existing analysis programs, ADINA and GIFTS, are studied to gain insights into their designs. These are the state-of-the-art analysis programs that create large databases. However their database management systems are

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tightly coupled to the program and cannot be used for any extensions. An intelligent and flexible database management system that has been implemented on the PRIME system is described. The system implements both the numerical and relational data models. These models are judged to be more suitable for engineering applications. A detailed description of the capabilities of the system is presented. Using the system, the proposed database design will be implemented and evaluated in the future.

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SUMMARY

This report presents a procedure for design of database for structural analysis and design optimization. The procedure involves three distinct steps: (i) collection of information, (ii) analysis of data flow and (iii) identification of relations and data sets. The procedure is used to design a database for analysis and design of systems for linear, nonlinear, static and dynamic responses. Databases of two existing analysis programs, ADINA and GIFTS, are studied to gain insights into their designs. These are the state-of-the-art analysis programs that create large databases. However their database management systems are tightly coupled to the program and cannot be used for any extensions. An intelligent and flexible database management system that has been implemented on the PRIME system is described. The system implements both the numerical and relational data models. These models are judged to be more suitable for engineering applications. A detailed description of the capabilities of the system is presented. Using the sytem, the proposed database design will be implemented and evaluated in the future.

1. INTRODUCTION

Analysis and design of engineering systems involves operations on a large amount of data. With the availability of sophisticated database management systems, the data can be organized effectively in databases. A good database containing all the relevant information required in analysis and design will enable designers to use the data in an efficient manner. With the aid of a database, engineer seeks the required data directly from the database instead by conventional means such as charts and tables. The data stored in a database may be used either interactively or through application programs. During design process, new data is created and existing data in the database is modified. Database may become highly disorganized and unmanageable unless it is designed properly to allow systematic use of data. Therefore, design of efficient database is one of the important tasks needed for engineering system design and its optimization.

A database is defined as a collection of interrelated data stored together without harmful or unnecessary redundancy to serve multiple applications. The data are stored so that they are independent of programs which use the data. A common and controlled approach is used in adding new data and in modifying and retrieving existing data within the database. The data is structured so as to provide a foundation for future application development. It is important to note that database contains actual data as well as the relationship between data values.

Users in the field of structural analysis and design optimization can be application program developers, interactive users, structural system design program developers, and the database administrator. Application programmers are involved in developing special applications which are not available in existing structural design programs. However, an interactive user is generally concerned with quick retrieval and storage of data required in arbitrary sequence of computation. System program developers are those who need well-organized database to develop system analysis and design packages in an efficient way. Thus, it is necessary to cater to the need of all these users by a well-designed database.

Database design is a complex task and requiring a systematic approach and a suitable design methodology. It starts with collection of all relevant information needed in system analysis and design optimization. All the user's requirements have to be met in the design of database. The existing databases available for structural analysis and design have to be studied. The method of data organization and their good and weak aspects have to be analyzed. This will enable the new database to be designed to incorporate all the favorable features of existing databases and avoid all the weaknesses that might arise in the new database.

This report deals with the database design for structural analysis and design optimization. It is critically important to properly design a database for such applications. These applications need dynamic interaction with the database; i.e., during the run-time data needs to be fetched and new data needs to be created in the database. Improperly designed database can be more harmful than helpful. the program can be highly inefficient if a proper database is not designed and the database management system is not highly sophisticated. This report present various steps and detailed design of a database. Databases of two well known existing finite element programs for analysis of complex systems are studied. These programs can handle linear, nonlinear, static, and dynamic analysis of advanced systems. Insights gained from the study of these databases are used to design a new database.

The requirements of a database for structural design applications are given in Chapter 2. The concepts of global and local databases are explained. Techniques of data organization are also given there. Details of ADINA's database are described in Chapter 3. Analysis of GIFTS database is given in Chapter 4. Data required for FEM-based structural synthesis are described in Chapter 5. A new database is designed in Chapter 6 based on the database requirements of Chapter 2. A database management system suitable for engineering analysis and design is described in Chapter 7. Finally, discussion and conclusions are given in the last chapter.

2. DATABASE DESIGN PROCEDURES

2.1 INTRODUCTION

For a good database design, certain well-defined procedures must be followed to meet the specified requirements. Before a database is designed, required information is collected. The information is organized to develop a data model. Based on this, we can design a suitable database meeting requirements of several application programs and interactive use. In this chapter, detailed requirements of a database, some guidelines for information collection and data organization, and concepts of global and local database are given.

A comprehensive survey of database management concepts and systems has been recently presented (Sreekanta Murthy, et al, 1983; Sreekanta Murthy, Reddy, and Arora, 1984; Sreekanta Murthy and Arora, 1984). These reviews indicate that the use of database management in scientific computing is increasing. The subject has become quite mature in business type applications. Considerable work needs to be done to properly design databases in engineering application. The scientific community has recoganized this need. Therefore research efforts in the area have seen a steady growth in the recent years. General description and concepts of database management in scientific computing have been presented by Fellipa (1979, 1981). Data management in finite element analysis has been studied by Pahl (1981). Data management in FEM-Based optimization software has been discussed by Rajan and Bhatti (1983). The role and application of database management in integrated computer-aided design has been discussed by Blackburn, Storaasli and Fulton (1982). It can be observed from this review that the importance of data management and proper database design have been well recoganized. It is expected that suitable methods and systems will be developed and reported. More databases will be designed and implemented for engineering applications.

2.2 WHY A DATABASE IS NEEDED?

Computer programs for optimal design of large structural and mechanical systems can be developed for automatic computation based on well-known design optimization methods. Finite element techniques are usually adopted to analyze a system within a design iteration. In general, finite element techniques require large computation time and data storage. Furthermore, the amount of data handled is directly dependent on the number of iterations performed in iterative schemes. Therefore, a careful consideration of data handling aspect is necessary in design optimization.

It is important to realize that engineering design optimization and engineering analysis are fundamentally different in nature. In analysis, it is generally assumed that a solution exists and numerical methods used are stable. Also, many engineering problems require use of the data only a few times during the solution procedure. In optimal design, on the other hand, we find solutions in an iterative manner. Existence of even a nominal design satisfying constraints is not assumed, much less existence of an optimal design. Therefore, it becomes essential for the designer to exercise control over the suitable design optimization method that has to be used. In such a case, the data used by one method should be made available for use in another method. The concept of centralized database becomes important. A centralized database which allows interaction between a finite element program and an optimization program can be used to improve design iteratively. Such a database provides an option for the designer to interrupt the program execution and provides flexibility for designer to change the design parameters. With a properly designed database when used in conjunction with interactive computer graphics offers a considerable aid to the engineer involved in design optimization.

2.3 REQUIREMENTS OF DATABASE

General requirements of a database for structural analysis and design optimization are identified as follows:

(1) It should include all the data needed for structural analysis and design.

(2) It should serve many applications and interactive needs.

(3) It should be designed so that new types of data and new applications can be easily added.

(4) It should allow individual perspectives of data. This means that if a particular user needs only a portions of data from database, provision of data access in parts must be available.

(5) *Data redundancy should be minimized. Duplication of data in the* database must be avoided.

(6) It should have flexibility for data manipulation (ADD, DELETE, INSERT, MODIFY)

(7) Suitable data structures should be allowed such as data sets, hierarchical and relational structure (Sreekanta Murthy, et al, 1983).

(8) It should be designed to allow for data classification based on use e.g., geometry data, material data, structural properties data, optimization data). This facilitates storing all related data in a database.

(9) It should contain accurate information and have data integrity. Data intergrity means the correctness of data in the database.

(10) It should hold consistent information in various data groups. Information about a particular data object represented in various data sets must be consistent. For example, Nodal coordinate data and nodal degree of freedom data must contain same value of node number.

(11) It should be independent of application programs. The database must be designed without any refernnce to any particular program. This will enable impartial design of database. Also, this makes the database suitable for any application program.

(12) Mechanisms for security and protection should be provided.

2.4 INFORMATION COLLECTION STEPS

Design of a database requires use of well defined step. Collection of information about the database is a first step. The following guidelines are used in information collection:

(1) Discuss with users of database and find out their requirements.

(2) Find out the data needed for analysis and optimization methods.

(3) Write down the sequence of data usage.

(4) Identify the data entities and assign a unique name to them.

(5) Determine their approximate size.

(6) Find out the properties of data entities. For example an entity 'Element' has properties such as Shape, Nodes, Material. Property identification will help in collecting data associated with a particular entity.

(7) Find out the data needed for possible future use.

2.5 ORGANIZATION OF DATA

Collected information based on the guidelines discussed in the previous section has to be grouped together according to their properties and relations. The most common way of grouping data is based on data sets or relations. Data set approach is based on organization of data into rows, columns, or submatrices. Relational approach is based on two-dimensional tabular form of data organization. Details of these two types of data organizations are discussed in this section.

2.5.1 Data Set

A data set is collection of data in the form of rows, columns, or submatrices. The data of same type are grouped together and identified using a unique name. The type of data sets can be short integer, long integer, single and double precision reals, or character words. Data storage and retrieval in the data sets are based on row and column identification numbers. A submatrix in a data set is located using its row and column numbers. Parts of data sets may be stored or retrieved by specifying appropriate elements of a row, column, or submatrix.

Data set approach is quite useful for organization of numerical data. Large-order matrices can be easily represented using submatrix data sets.

2.5.2 Relations

Tables are the most convenient way of representing some data. A relational data model is constructed from a tabular representation of data. The rows of the table are generally referred as tuples. The columns are referred as attributes. This model can be easily implemented and quite convenient to use. A relation can be easily expanded by addition of tuples. The relational algebraic operations such as PROJECT, JOIN, and SELECT can be used to form new relations. Figure 2.1 shows a typical relational model of data for finite element technique. Relation is named TRIG and contains tuples of triangular element data. There are six attributes for this relation; element, material and connected node numbers, and thickness.

A relation can contain data types of short or long integers, single or double precision real constants, and characters. Attributes of a relation can be of different data types. For example, element number in the relation TRIG is an integer, whereas thickness is a real data type.

2.6 GLOBAL AND LOCAL DATABASE

After the data are grouped into data sets or relations, next step is to store them in a database or many databases. One approach of storing data sets or relations is based on concept of global and local databases. A global database is a central depository of data needed in many applications or users. The global database is useful in collecting all data which are common to many applications or users. Whereas a local database is used by a single user or application. The local database contains only the data required for an application program or part of the application program.

The global and local database concept is quite useful in structural analysis and design optimization. The data such as geometry, material properties, and details of structural member of a system can be stored in a global database. The application programs retrieve these data to perform various computations. During the process of computation, intermediate results have to be saved in a local database. Once the analysis and design of the structural system is finalized, the results are transfered to global database for future use.

It is possible to provide various security and protection mechanisms using global and local databases. Only those with authorized password can be allowed to access parts of the global data. "Read Only" or "Modifying Access" can be provided to various data sets. This allows consistent modification of data in databases.

TRIG

ELEMENT NO.	MATERIAL NO.	NODE 1	NODE 2	NODE 3	THICKNESS

Figure 2.1 Typical Relational Data Model

3. ANALYSIS OF ADINA DATABASE

3.1 INTRODUCTION

Designing an efficient database for structural analysis and design optimization needs an investigation of databases for the existing analysis programs. Among them, ADINA has been known to be an efficient, reliable and well-written program for linear and nonlinear static and dynamic analysis. This chapter presents details of ADINA database and related materials. Since our concern is analysis of ADINA's database, subsequent sections are devoted to the structure of program, database in ADINA and explaination of database files.

Section 3.2 contains flow of input data in ADINA. Section 3.3 describes the concept of ADINA. Its database structure is summarized in Section 3.4. Details of each tape (file) are given in Section 3.5.

3.2 FLOW OF INPUT DATA IN ADINA

This section contains the flow of input data in ADINA is described in this section. More details are given in ADINA User's Manual (Report AE81-1).

I. HEADING CARD

II. MASTER CONTROL CARDS
Card 1 - Structural Control Card
Card 2 - Structural Control Card
Card 3 - Load Control Card
Card 4 - Mass and Damping Control Card
Card 5 - Frequency Solution Control Card
Card 6 - Time Integration Method Control Card
Card 7 - Incremental Solution Strategy Control Card
Card 8 - Print-Out Directives Control Card
Card 9 - Porthole Creation Control Card

III. SOLUTION DETAILS CARDS
1. Block Definition Cards for Effective Stiffness Matrix Reformation Time Steps
2. Block Definition Cards for Equilibrium Interation Time Steps
3. Block Definition Cards for Print-Out Time Steps
4. Block Definition Cards for Nodal Quantities Print-Out
5. Block Definition Cards of Time Steps for Saving Nodal Response
6. Block Definition Cards of Time Steps for Saving Element Responses

IV. TIME FUNCTIONS DATA
1. Time Functions Control Card
2. Time Functions Data

V. NODAL POINT DATA
1. Definition of Skew Coordinate Systems
2. Defintion of Mid-surface Normal Vector Sets
3. Nodal Point Data
4. Displacement Constriants Data

VI. STRUCTURAL MASSES, DAMPERS AND MODAL DAMPING FACTORS

1. Concentrated Masses
2. Concentrated Dampers
3. Modal Damping Factors

VII. INITIAL CONDITIONS

a. control card
b. card input of initial nodal-point displacements, volocities and accelerations
c. card input of initial temperatures

XI. TRUSS ELEMENTS

1. Element Group Control Card
2. Section and Material Property Data Cards
3. Element Data Cards

XII. 2/D SOLID ELEMENTS

1. Element Group Control Cards
2. Material Property Data Cards
3. Stress Output Table Cards
4. Element Data Cards

XIII. 3/D SOLID ELEMENTS

1. Element Group Control Card
2. Material Property Data Cards
3. Stress Output Table Cards
4. Element Data Cards

XIV. BEAM ELEMENT

1. Element Group Control Card
2. Geometric and Material Linear Section Property Cards
3. Nonlinear Beam Property Cards

4.1 End Release Table

4.2 Stress Output Table Cards

5. Element Data Cards

XV. ISOPARAMETRIC BEAM ELEMENTS

1. Element Group Control Card
2. Section and Material Property Data Cards
3. Stress Output Table Cards
4. Element Data Cards

XVI. PLATE/SHELL ELEMENT

1. Element Group Control Card
2. Material Property Data Cards
3. Stress-Resultant Output Table Cards
4. Element Data Cards

XVII. SHELL ELEMENTS

1. Element Group Control Card
2. Material Propety Data Cards
3. Stress Output Table Cards
4. Shell Thickness Table Cards
5. Element Data Cards

XXI. 2/D FLUID ELEMENTS
1. Element Group Control Card
2. Material Property Data Cards
3. Element Data Cards

XXII. 3/D FLUID ELEMENTS
1. Element Group Control Card
2. Material Propety Data Cards
3. Element Data Cards

XXXII. APPLIED LOADS DATA
A. Structure Loads Data
1. Concentrated Loads Data
2. 2/D Pressure Loading Data in Y-Z Plane
3. 3/D Pressure Loading Data
4. 2-Node BEAM Distrubted Loading Data
5. ISO/BEAM Distributed Loading Data
6. PLATE/SHELL Pressure Loading Data
7. SHELL Pressure Loading Data
8. Mass Proportional Loading Data
9. Nodal Temperature Data
10. Nodal Temperature Data
B. Substructure Loads Data

XXXIII. FREQUENCY CALCULATION CARD
a. determinant search solution card
b. subspace iteration method card

3.3 STRUCTURE OF ADINA

In this section, concise description of program ADINA is given. More details can be found in ADINA reports and Bathe (1982).

3.3.1 What is ADINA?

ADINA (Automatic Dynamic Incremental Nonlinear Analysis) is a computer program for the static and dynamic displacemnt and stress analysis of solids, structures and fluid-structure systems. The program can be employed to perform linear and nonlinear analysis. Since in many cases only a linear analysis is required, and a nonlinear analysis should be preceded by a linear analysis, the program has been designed to perform a linear analysis very effectively. Following a linear analysis, a nonlinear analysis can be carried out with only a relatively few input changes. The companion program ADINAT is for analysis of linear and nonlinear, steady state and transient heat transfer problems.

3.3.2 Organization of ADINA

The complete solution process in program ADINA is divided into four distinct phases:

1) Finite Element Mesh and Element Data Input

In this phase the control information and the nodal point input data are read and generated by the program. The equation numbers for the active degrees of freedom at each nodal point are established. The initial conditions are read. The element data are read and generated, the element connection arrays are calculated and all element information is stored on a tape (database file).

2) Assemblage of Constant Structure Matrices

Before the solution of equilibrium equations is carried out, the linear structural stiffness, mass, and damping matrices are assembled and stored on tape (or other low-speed storage). In addition, the effective linear structural stiffness matrix (combination of stiffness, damping and mass matrices) is calculated and stored.

3) Load Vector Calculations

The externally applied load vectors for each time (load) step are calculated and stored on a tape.

4) Step-by-Step Solution

During this phase solution of the equilibrium equations is obtained at all time (or load) points. In addition to the displacement, velocity, and acceleration vectors (whichever applicable), the element stress are calculated and printed. Before the time integration is performed, the lowest frequencies and corresponding mode shapes may be calculated. In linear analysis, dynamic solution can be obtained using mode superposition.

3.3.3 Available Elements

The program ADINA presented contains the following element types:

(1) Truss elements
(2) Two-dimensional solid elements
(3) Three-dimensional solid elements
(4) Beam element
(5) Isoparametric beam elements
(6) Plate/shell element
(7) Shell elements
(8) 2-D fluid elements
(9) 3-D fluid elements

3.3.4 Available Material Models

Depending on the element type, the following material descriptions are presently available in ADINA.

For Truss Elements
(a) linear elastic
(b) nonlinear elastic
(c) thermo-elastic
(d) elastic-plastic
(e) thermo-elastic-plastic and creep

For Two-dimensional Elements
(a) isotropic linear elastic
(b) orthotropic linear elastic
(c) isotropic thermo-elastic
(d) curve description model
(e) concrete model
(f) elastic-plastic materials, von Mises and Drucker-Prager yield conditions
(g) thermo-elastic-plasti-creep, von Mises yield condition
(h) Mooney-Rivlin material

For Three-dimensional Elements
(a) isotropic linear elastic
(b) orthotropic linear elastic
(c) isotropic thermo-elastic
(d) curve description model
(e) concrete model
(f) elastic-plastic materials, von Mises and Drucker-Prager yield conditions
(g) thermo-elastic-plastic-creep, von Mises yield condition

For Two-node Beam Element
(a) linear elastic
(b) elastic-plastic, von Mises yield condition

For Isoparametric Beam Elements
(a) linear elastic
(b) elastic-plastic, von Mises yield condition

For Three-node Plate/Shell Element
(a) isotropic linear elastic
(b) orthotropic linear elastic
(c) elastic-plastic, Ilyushin yield criterion

For Shell Element
(a) linear elastic
(b) elastic-plastic, von Mises yield condition

3.3.5 Usage of ADINA

In the preceding subsections, ADINA was introduced as a computer program for the static and dynamic displacement and stress analysis of solids, structures and fluid-structure systems. Because ADINA is one of the most well-tested and reliable linear and nonlinear static and dynamic analysis program, it can be used as an analysis module for any design optimization program. As an example, one can couple program ADINA with the design optimization computer program such as IDESIGN to optimize some realistic structures. Various nonlinear (material and geometric) analysis capabilities of ADINA offers a wide range of nonlinear design optimization applications. In the near future, coupling of ADINA and IDESIGN will be accomplihsed.

3.4 DATABASE IN ADINA

The database of ADINA is organized in several files. With a little effort, it is possible to access any information from the database.

Program ADINA opens 25 files at the beginning of execution and dumps the given and generated data into them (in ADINA, they are called Tapes). Following subsections describe the database file (i.e., sequential or random access, formatted or unformatted record length of each file, and unit number on which the file is opened).

3.4.1 Tape Allocation

Depending on the required information, ADINA stores various data on sequential access files (except tapes 2, 10, 16, and 17) or random access files (tapes 2, 10, 16, and 17).

TAPE 1 stores linear element group data, and stores also substructures element group data

TAPE 2 stores nonlinear elements group data

TAPE 3 stores externally applied loads

TAPE 4 stores the linear stiffness matrix
(when NEGL.NE.0 .or. NSUBST.NE.0 only)

TAPE 5 is the input file generated for execution when comment cards are allowed in the input stream otherwise it is the initial input file

TAPE 6 is the output tape

TAPE 7 stores effective linear stiffness matrix in direct time integration, and used as scratch file during model superpositon analysis

TAPE 8 stores sequentially
(1) ID array
(2) during input
initial DISP, VEL, ACC vectors
on output final DISP, VEL, ACC vectors and nonlinear element group data for restart

TAPE 9 stores mode shapes and circular frequencies (if frequency solution was requested), and used as a scratch file during equilibrium iteration

TAPE 10 stores D - L factors of effective linear or nonlinear stiffness matrix in tme integration

TAPE 11 stores sequentially
(1) mass matrix (consistent mass if IMASS.EQ.2)
(2) damping vector

TAPE 12 is initially used as scratch in load calculation
stores the effective nonlinear stiffness matrix in the time integration, for the nonlinear stiffness matrix for eigensystem solution

TAPE 13 stores initially time function values and prescribed displacements data during time integration

TAPE 14 stores substructures data

TAPE 15 stores load vector for each time, substructure ID arrays and master structure nodal responses at all time steps

TAPE 16 stores substructure factorized stiffness matrices

TAPE 17 stores substructure nodal loads for all time steps

TAPE 18 stores data in BFGS interation and vectors input to subspace iteration, also temporarily stores reduced substructure stiffnesses

TAPE 19 stores vectors in subspace iteration

TAPE 22 stores load vector during equilibrium iteration

TAPE 23 stores substructure nodal responses at all time steps, and temporarily stores concentrated masses and dampers

TAPE 50 is the initial input file in which comment cards are included in the input stream

TAPE 56 stores nodal point temperatures

TAPE 59 stores preprocessed input data (if used)

TAPE 60 is the porthole (graphics) file for saving nodal/element responses (if requested)

3.4.2 Details of Opening/Closing Files

On prime system, current version of ADINA has the following options for each file: form (formatted or unformatted), access (sequential or random access file), and recl (record length) for each database (tape-file).

TAPE 1 form=unformatted, access=sequential, recl=4000

TAPE 2 access=direct, recl=12000

TAPE 3	form=unformatted, access=sequential, recl=1000
TAPE 4	form=unformatted, access=sequential, recl=1000
TAPE 5	ADINA•IN, status=old
TAPE 6	ADINA• OUT, status=unknown
TAPE 7	form=unformatted, access=sequential, recl=4000
TAPE 8	form=unformatted, access=sequential, recl=4000
TAPE 9	form=unformatted, access=sequential, recl=4000
TAPE 10	access=direct, recl=12000
TAPE 11	form=unformatted, access=sequential, recl=1000
TAPE 12	form=unformatted, access=sequential, recl=1000
TAPE 13	form=unformatted, access=sequential, recl=1000
TAPE 14	form=unformatted, access=sequential, recl=1000
TAPE 15	form=unformatted, access=sequential, recl=1000
TAPE 16	access=direct, recl=12000
TAPE 17	access=direct, recl=12000
TAPE 18	form=unformatted, access=sequential, recl=1000
TAPE 19	form=unformatted, access=sequential, recl=1000
TAPE 22	form=unformatted, access=sequential, recl=1000
TAPE 23	form=unformatted, access=sequential, recl=1000
TAPE 50	form=unformatted, access=sequential, recl=1000
TAPE 56	form=unformatted, access=sequential, recl=1000
TAPE 59	form=formatted, access=sequential, recl=4000
TAPE 60	form=unformatted, access=sequential, recl=4000

3.5 DATABASE FILES IN ADINA

This section contains detailed description of each database file in ADINA.

3.5.1 Tape 1

Specifications:

- sequential access file
- stores linear element group data, also stores substructures element group data.

TAPE 1 Element Group: Truss

Description	Variable	Dimension
Element group control information	NPAR	20

NPAR:
NPAR(1)=1

NPAR(2) Number of truss element in this group

NPAR(3) Type of nonlinear analysis
0. linear analysis
1. materially nonlinear only
2. updated Lagragian formulation

NPAR(4) Element birth and death option
0. elements are active through the solution
1. elements becomes only active at the time of birth
2. elements becomes inactive at the time of death

NPAR(5) Element type code
0. general 3-D truss
1. axisymmetric truss (ring)

TAPE 1 Element Group: Truss (Continued)

Description		Variable	Dimension
NPAR(6)	Skew coordinate system reference indicator 0. all element nodes use the global system only 1. some element node d.o.f. are referred to a skew coordinate system		
NPAR(7)	Maximum no. of nodes used to describe any one element		
NPAR(10)	Numerical integration order to be used in Gauss quadrature formula		
NPAR(15)	Material model number 0. default set to 1 1. linear elastic 2. nonlinear elastic 3. thermo-elastic 4. elastic-plastic (isotropic) 5. elastic-plastic (kinematic) 6. thermo-elastic-plastic and creep (isotropic) 7. thermo-elastic-plastic and creep (kinematic)		
NPAR(16)	Number of different sets of material/ section properties		
NPAR(17)	Number of material model constants for NPAR(15)=2		
Mass density		DEN	NPAR(16)
Cross sectional area		AREA	NPAR(16)

TAPE 1 Element Group: Truss (Continued)

Description	Variable	Dimension
Nodal D.O.F. number	LM	3*NPAR(7)*NPAR(2)
Element nodal coordinates	XYZ	3*NPAR(7)*NPAR(2)
Material property set number	MATP	NPAR(2)
Element initial strain	EPSIN	NPAR(2)
Stress printing flag	IPS	NPAR(2)
Element birth/death time	ETIMV	MM*NPAR(2) MM=1 IF NPAR(4)>0
Element displacement at birth time	EDISB	MM*3*NPAR(7)*NPAR(2) MM=1 IF NPAR(4)>0
Working array	WA	NPAR(2)*NPAR(18)*NPAR(10)
Material constants	PROP	NPAR(17)*NPAR(16)
NPAR(15):= 1. Young's modulus 2. strain at point 1, e^1 strain at point 2, e^2 ... ... strain at point NPAR(17)/2 stress at point 1, σ^2 stress at point 2, σ^2 ... ... stress at point NPAR(17)/2 3. temperature at point 1, θ_1 temperature at point 2, θ_2 ... ... temperature at point 16, θ_{16}		

TAPE 1 Element Group: Truss (Continued)

Description	Variable	Dimension
Young's modulus at point 1, E_1		
Young's modulus at point 2, E_2		
...		
...		
Young's modulus at point 16, E_{16}		
mean coefficient of thermal expansion at point 1, α_1		
mean coefficient of thermal expansion at point 2, α_2		
...		
...		
mean coefficient of thermal expansion at point 16, α_{16}		
XNPTS = number of temperature point default set to 16		
TREF = reference temperature		
4. Young's modulus, E		
initial yield stress, σ_y		
strain hardening modulus, E_T		
5. Young's modulus, E		
initial yield stress, σ_y		
strain hardening modulus, E_T		
6. temperature at point 1, θ_1		
temperature at point 2, θ_2		
...		
...		
temperature at point 16, θ_{16}		

TAPE 1 Element Group: Truss (Continued)

Description	Variable	Dimension
Young's modulus at point 1, E_1		
Young's modulus at point 2, E_2		
...		
...		
Young's modulus at point 16, E_{16}		
yield stress in simple tension at point 1, σ_{y_1}		
yield stress in simple tension at point 2, σ_{y_2}		
...		
...		
yield stress in simple tension at point 16, $\sigma_{y_{16}}$		
strain hardening modulus in simple tension at point 1, E_{T_1}		
strain hardening modulus in simple tension at point 2, E_{T_2}		
...		
...		
strain hardening modulus in simple tension at point 16, $E_{T_{16}}$		
mean coefficient of thermal expansion at point 1, α_1		
mean coefficient of thermal expansion at point 2, α_2		
...		
...		

TAPE 1 Element Group: Truss (Continued)

Description	Variable	Dimension
mean coefficient of thermal expansion at point 16, α_{16}		
creep law constants a_0		
...		
...		
creep law constants a_7		
XNPTS = number of temperature point = 0, default set to 16		
XREF = reference temperature		
XKCRP = creep law number		
ALPHA = time integration parameter		
XISUBM = maximum number of time step subdivisions = 0; default set to 10		
XINTE = maximum number of iteration per subdivision = 0; default set to 15		
XNALA = algorithm in indicactor 0. set to 1 1. equal subdivisons are used per time step 2. self-adaptive size subdivisions are used per time step		

TAPE 1 Element Group: Truss (Continued)

Description	Variable	Dimension
TOLIL = stress calculation convergence tolerance = 0; default set to 0.005 TOLPC = inealstic strain tolerance = 0; default set to 0.10		
Global node number	NODGL	3*NPAR(7)*NPAR(2)*NPAR(7)
Element number of nodes	IDELTD	NPAR(2)
Skew coordinates flag	ISKEW	NPAR(2)*NPAR(7)

TAPE 1 Element Group: 2/D Solid Elements

Description	Variable	Dimension
Element group control information	NPAR	20

NPAR:

NPAR(1)= 2

NPAR(2) Number of 2/D solid element in this group

NPAR(3) Code indicating type of nonlinear analysis

- 0. linear analysis
- 1. material nonlinear analysis
- 2. total Lagrangian
- 3. updated Lagrangian

NPAR(4) Element birth and death option

- 0. elements are active throughout solution
- 1. elements become only active at the time of birth
- 2. elements become inactive at the time of death

NPAR(5) Element type code

- 0. axisymmetric
- 1. plane strain
- 2. plane stress
- 3. 3-D plane stress

NPAR(6) Skew coordinate system reference indicator

TAPE 1 Element Group: 2/D Solid Elements (Continued)

	Description	Variable	Dimension
	0. all element nodes use the global system only 1. some element node d.o.f. are referred to a skew coordinate system		
NPAR(7)	Maximum number of nodes used to describe any one element		
NPAR(8)	Degeneration indicator 0. number spatial isotropy correction 1. degenrated 8-node elements (side 1-8-4) are spatially isotropic		
NPAR(10)	Numerical integration order to be used in Gauss quadrature formula		
NPAR(13)	Number of stress output location tables 0. output stresses at integration points		
NPAR(15)	Material model number > 0 and < 14 0. default set to 1 1. isotropic linear elastic		

TAPE 1 Element Group: 2/D Solid Elements (Continued)

	Description	Variable	Dimension
	2. orthotropic linear elastic 3. isotropic thermo-elastic 4. curve description (with tension act-off or cracking) 5. concrete (with cracking and crushing) 6. empty 7. elastic-plastic (Drucker-prager-cap) 8. elastic-plastic (von Mises, isotropic hardening) 9. elastic-plastic (von Mises, kinematic hardening) 10. thermo-elastic plastic and creep (von Mises isotropic hardening) 11. thermo-elastic-plastic and creep (von Mises, kinematic hardening) 12. empty 13.incompressible nonlinear elastic (Mooney-Rivlin plane stress only) 14. user-supplied		
NPAR(16)	Number of different sets of material properties		

TAPE 1 Element Group: 2/D Solid Elements (Continued)

Description	Variable	Dimension
NPAR(17) Number of constants per property set for NPAR(15) 8. multilinear model 9. multilinear model 14. user supplied otherwise not applicable		
NPAR(20) Dimension of storage array required for element history 0. if NPAR(15) < 14. > 0 if NPAR(15) = 14		
Nodal D.O.F. number	LM	2*NPAR(7)*NPAR(2)
Element nodal coordinates	YZ	2*NPAR(7)*NPAR(2)
Element number of nodes	IELT	NPAR(2)
Stress printing flag	IPST	NPAR(2)
Element material angle	BETA	NPAR(2)
Element thickness	THICK	NPAR(2)
Material property set number	MATP	NPAR(2)
Mass density set number	DEN	NPAR(16)
Material constants	PROP	NPAR(17)*NPAR(16)
NPAR(15): 1. Young's modulus, E possior's ratio, ν 2. a-direction modulus, E_a b-direction modulus, E_b		

Description	Variable	Dimension
c-direction modulus, E_c		
strain ratio, ν_{ab}		
strain ratio, ν_{ac}		
strain ratio, ν_{bc}		
shear modulus, G_{ab}		
3. temperature at point "1", θ_1		
...		
temperature at point "16", θ_{16}		
Young's modulus at point "1", E_1		
...		
Young's modulus at point "16", E_{16}		
Poisson's ratio at point "1", ν_1		
...		
Poisson's ratio at point "16", ν_{16}		
mean coefficient of thermal expansion at point "1", α_1		
...		
mean coefficient of thermal expansion at point "16", α_{16}		
XNPTS = number of temperature points EQ.0; default set to 16		
TREF = reference temperature		
4. e_V^1 volume straint at point "1"		
e_V^2 ...		

Description	Variable	Dimension
e^3_V		
e^4_V		
e^5_V		
e^6_V		
K^1_{LD} loading bulk modulus at point "1"		
K^2_{LD} •••		
K^3_{LD}		
K^4_{LD}		
K^5_{LD}		
K^6_{LD}		
K^1_{UN} unloading bulk modulus point "1"		
K^2_{UN} •••		
K^3_{UN}		
K^4_{UN}		
K^5_{UN}		
K^6_{UN}		
G^1_{LD} loading shear modulus at point "1"		
G^2_{LD} loading shear modulus at point "2"		
G^3_{LD} •••		
G^4_{LD}		

TAPE 1 Element Group: 2/D Solid Elements (Continued)

Description	Variable	Dimension
G_{LD}^{5}		
G_{LD}^{6}		
5. tangent modulus at zero strain, $\tilde{E}_0$		
6. Poisson's ratio, ν		
7. Young's modulus, E		
Poisson's ratio, ν		
Yield function parameter, α		
Yield function parameter, k		
Cap hardening parameter, W		
Cap hardening parameter, D		
Tension cut-off limit, T		
Initial cap position, ${}^{0}I_{1}^{a}$		
8. & 9.		
a. bilinear elastic-plastic model		
Young's modulus, E		
Poisson's atio, ν		
Yield stress in simple tension σ_y		
Strain hardening modulus, E_T		
b. multilinear elastic-plastic model		

Description	Variable	Dimension
Young's modulus, E		
Poisson's ratio, ν		
Yield stress, σ_1		
Yield strain, ε_1		
Stress at point 2		
Strain at point 2		
Stress at point 3		
Strain at point 3		
Stress at point 4		
Strain at point 4		
. . .		
Stress at point 7		
Strain at point 7		
10. & 11.		
θ_1 temperature at point "1"		
θ_2 ...		
θ_{16} temperature at point "16"		
E_1 Young's modulus at point "1"		
E_2 ...		
E_{16} Young's modulus at point "16"		

Description	Variable	Dimension
	ν_1 Poisson's ratio at point "1"	
	ν_2 •••	
	ν_{16} Poisson's ratio at point "16"	
	σ_{y_1} yield stress in simple tension at point "1"	
	σ_{y_2} •••	
	$\sigma_{y_{16}}$ yield stress in simple tension at point "16"	
	E_{T_1} strain hardening modulus in simple tension at point	
	E_{T_2} •••	
	$E_{T_{16}}$ strain hardening modulus in simple tension at point "16"	
	α_1 mean coefficient of thermal expansion at point "1"	
	α_2 •••	

TAPE 1 Element Group: 2/D Solid Elements (Continued)

Description	Variable	Dimension
	α_{16} mean coefficient of thermal expansion at point "16"	
	a_0 creep law constants	
	a_1 ...	
	a_7 creep law constants	
	XNPTS = number of temperature points EQ.0; default set to 16.	
	TREF = reference temperature	
	XKCRP = creep law number	
	ALPHA = time integration parameter	
	XISUBM = maximum number of time step subdivisions EQ.0; default set to 10.	
	XNITE = maximum number of iteration per subdivision EQ.0; default set to 15.	
	XNALG = algorithm indicator EQ.0; default set to 1. EQ.1; equal size subdivisions are used per time step	

TAPE 1 Element Group: 2/D Solid Elements (Continued)

Description	Variable	Dimension
EQ.2; self-adaptive size subdivisions are used per time step TOLIL = stress calcualtion convergence tolerance EQ.0; default set to .005 TOLPC = inelastic strain tolerance EQ.0; default set to .10 13. C_1 C_2 14. (prop (J,N),J=1, NPAR(17), N=1,NPAR(16))		

Working array	WA	NPAR(20)*NPAR(10)**2*NPAR(2)
		IF(NPAR(19)>0)THEN
		NDWS(NPAR(15))*(NPAR(15))* NPAR(7)

Midside nodes	NOD5	NPAR(7)-4
Element expiry time array	ETIMV	MM*NPAR(2) IF(NPAR14)=1)MM=1
Element birth time nodal coordinates	EDISB	MM*NPAR(2)*2*NPAR(7) IF(NPAR(4)=1)MM=1
Stress output location tables	ITABLE	NPAR(13)
Stress out location 1		
Stress out location 2		
Stress out location 3		

TAPE 1 Element Group: 2/D Solid Elements (Continued)

Description	Variable	Dimension
Stress out location 4		
Stress out location 5		
Stress out location 6		
Stress out location 7		
Stress out location 8		
Stress out location 9		
Skew coordinates flag	ISKEW	MM*NPAR(2)*NPAR(7) IF(NPAR(6)>0)MM=1
Spatial isotropy correction indicator	ISO	MM*NPAR(2) IF(NPAR(8)>0)MM=1
Displacement at previous step	PDIS	2*NPAR(7)*NPAR(2)

TAPE 1 Element Group: 3/D Solid Elements

Description	Variable	Dimension
Element group control information	NPAR	20

NPAR:

NPAR(1)= 3

NPAR(2) Number of 3/D SOLID elements in this group

NPAR(3) Flag indicating type of nonlinear analysis
- 0. linear analysis
- 1. material nonlinear analysis only
- 2. total Lagrangian
- 3. updated Lagrangian

NPAR(4) Element birth and death option
- 0. elements are active throughout solution
- 1. elements become only active at the time of birth
- 2. elements become inactive at the time of death

NPAR(6) Skew coordinate system reference indicator
- 0. all element nodes use the global system only
- 1. some element node d.o.f. are referred to a skew coordinate system

TAPE 1 Element Group: 3/D Solid Elements (Continued)

Description		Variable	Dimension
NPAR(7)	Maximum number of nodes used to describe any one element		
NPAR(8)	Degeneration indicator 0. no spatial isotropy corrections 1. degenrated 20-node elements are spatially isotropic (15-node prisms or 10-node tetrahedra)		
NPAR(10)	Numberical integration order to be used in Gauss quadrature formula for r-s plane		
NPAR(11)	Numerical integration order to be used in Gauss quadrature formula for t-direction		
NPAR(13)	Number of stress output location tables		
NPAR(15)	Material model number GE.0 and LE.12 0. default set to 1 1. isotropic linear elastic 2. orthotropic linear elastic 3. isotropic thermo-elastic 4. curve description (with tension cut-off or cracking)		

TAPE 1 Element Group: 3/D Solid Elements (Continued)

	Description	Variable	Dimension
	5. concrete (with cracking and crushing) 6. empty 7. elastic-plastic (Drucker-Prager-Cap) 8. elastic-plastic (von Mises, isotropic hardening) 9. elastic-plastic (von Mises, kinematic hardening) 10. thermo-elastic plastic and creep (von Mises isotropic hardening) 11. thermo-elastic-plastic and creep (von Mises, kinematic hardening) 12. user-supplied		
NPAR(16)	Number of different sets of material properties		
NPAR(17)	Number of constants per maerial property set for NPAR(15) 8.8 multilinear model 9. multilinear model 12. user supplied otherwise not applicable		
NPAR(18)	Number of material axes orientation sets (in orthotropic linear analysis)		

TAPE 1 Element Group: 3/D Solid Elements (Continued)

Description	Variable	Dimension
NPAR(20) Dimension of storage array required for element history		
Nodal D.O.F. number	LM	3*NPAR(17)*NPAR(2)
Element nodal coordinates	XYZ	3*NPAR(17)*NPAR(2)
Element number of nodes	IELT	NPAR(2)
Element geometry number of nodes	IELTX	NPAR(2)
Stress printing flag	IPST	NPAR(2)
Spatial isotropy correction indicator	ISO	NPAR(2)*NPAR(8)
Material property set number	MATP	NPAR(2)
Midside nodes	NOD9	(NPAR(7)-8)*NPAR(2)
Similar stiffness and mass matrices indicator	IREUSE	NPAR(2)
Mass density set number	DEN	NPAR(16)
Material constants	PROP	NPAR(17)*NPAR(16)
NPAR(15): 1. Young's modulus, E Poission's ratio, ν 2. a-direction modulus, E_a b-direction modulus, E_b c-direction modulus, E_c Strain ratio, ν_{ab} Strain ratio, ν_{ac} Strain ratio, ν_{bc}		

Description	Variable	Dimension
	Shear modulus, G_{ab}	
	Shear modulus, G_{ac}	
	Shear modulus, G_{bc}	
3.	θ_1 temperature at point "1"	
	θ_2 •••	
	θ_{16} temperature at point "16"	
	E_1 Young's modulus at point "1"	
	E_2 •••	
	E_{16} Young's modulus at point"16"	
	ν_1 Poisson's ratio at point "1"	
	ν_2 •••	
	ν_{16} Poisson's ratio at point "16"	
	α_1 mean coefficient of thermal expansion at point "1"	
	α_2 •••	
	α_{16} mean coefficient of thermal expansion at point "16"	
	XNPTS = number of temperature points EQ.0; default set to 16.	
	TREF = reference temperature	
4.	e_V^1 volume strain at point "1"	
	e_V^2 •••	

Description	Variable	Dimension
e_V^3		
e_V^4		
e_V^5		
e_V^6 volume strain at point "6"		
K_{LD}^1 loading bulk modulus at point "1"		
K_{LD}^2 ...		
K_{LD}^3		
K_{LD}^4		
K_{LD}^5		
K_{LD}^6 loading bulk modulus at point "6"		
K_{UN}^1 unloading bulk modulus at point "1"		
K_{UN}^2 ...		
K_{UN}^3		
K_{UN}^4		
K_{UN}^5		
K_{UN}^6 unloading bulk modulus at point "6"		
G_{LD}^1 loading shear modulus at point "1"		

TAPE 1 Element Group: 3/D Solid Elements (Continued)

Description	Variable	Dimension
G^2_{LD} loading shear modulus at point "2"		
G^3_{LD} ...		
G^4_{LD}		
G^5_{LD}		
G^6_{LD}		
5. Tangent modulus zero strain, $\tilde{E}_0$		
Poisson's ratio ν		
7. Young's modulus, E		
Poisson's ratio, ν		
Yield function parameter, α		
Yield function parameter, k		
Cap hardening parameter, W		
Cap hardening parameter, D		
Tension cut-off limit, T		
Initial cap position, $O_{I}{}^{a}_{1}$		
8. & 9.		
a. bilinear elastic-plastic model		
Young's modulus, E		
Poisson's ratio, ν		
Yield stress in simple tension, σ_y		

TAPE 1 Element Group: 3/D Solid Elements (Continued)

Description	Variable	Dimension
Strain hardening modulus, E_T		
b. Multilinear elastic-plastic model		
Young's modulus, E		
Poisson's ratio, ν		
Yield stress, σ_1		
Yield strain, ε_1		
Stress at point 2		
Strain at point 2		
Stress at point 3		
Strain at point 3		
Stress at point 4		
Strain at point 4		
. . .		
Stress at point 7		
Strain at point 7		
10. & 11.		
θ_1 temperature at point "1"		
θ_2 ...		
θ_{16} temperature at point "16"		
E_1 Young's modulus at point "1"		
E_2 ...		

TAPE 1 Element Group: 3/D Solid Elements (Continued)

Description	Variable	Dimension
	E_{16} Young's modulus at point "16"	
	ν_1 Poisson's ratio at point "1"	
	ν_2 •••	
	ν_{16} Poisson's ratio at point "16"	
	σ_{y_1} yield stress in simple tension at point "1"	
	s_{y_2} •••	
	$\sigma_{y_{16}}$ yield stress in simple tension at point "16"	
	E_{T_1} strain hardening modulus in simple tension at point "1"	
	E_{T_2} •••	
	$E_{T_{16}}$ strain hardening modulus in simple tension at point "16"	
	α_1 coefficient of thermal expansion at point "1"	

Description	Variable	Dimension
	α_2 ...	
	α_{16} coefficient of thermal expansion at point "16"	
	a_0 creep law constants	
	a_1 ...	
	a_7 creep law constants	
	XNPTS = number of temperature points EQ.0; default set to 16.	
	TREF = reference temperature	
	XKCRP = creep law number	
	ALPHA = time integration parameter	
	XISUBM = maximum number of time step subdivisions EQ.0; default set to 10.	
	XNITE = maximum number of iteration per subdivision EQ.0; default set to 15.	
	XNALG = algorithm indicator EQ.0; default set to 1. EQ.1; equal size subdivisions are used per time step	

TAPE 1 Element Group: 3/D Solid Elements (Continued)

Description	Variable	Dimension

EQ.2; self-adaptive size sub-divisions are used per time step
TOLIL = stress calcualtion convergence tolerance
TOLPC = inelastic strain tolerance
12. (prop(N,N),
J=1,NPAR(17),
N=1,NPAR(16)		

Working array	WA	NPAR(20)*NPAR(10)**2*NPAR(11)
		IF(NPAR(19)>0)NDWS
		(NPAR(15))*(NPAR(7))*
		NPAR(2)

Element expiry time array	ETIMV	MM*NPAR(2) IF NPAR14)>1 MM=1
Element birth time nodal coordinates	EDISB	MM*NPAR(2)*3*NPAR(7) IF NPAR(4)>1 MM=1
Stress output location tables	ITABLE	NPAR(13)
Stress out location 1		
Stress out location 2		
...		
Stress out location 16		
Direction cosine arrary (if NPAR(15)=0)	DCA	NPAR(18)
Material axis orientation storage vector	MAXESV	NPAR(2)
Skew coordinates flag	ISKEW	NPAR(2)*3*NPAR(7)
Displacement at previous steps	PDIS	NPAR(2)*3*NPAR(7)

TAPE 1 Element Group: Beam Elements

Description	Variable	Dimension
Element group control information	NPAR	20
NPAR: NPAR(1)= 4		
NPAR(2) Number of BEAM elements in this group		
NPAR(3) Code indicating type of nonlinear analysis 0. linear analysis 1. material nonlinear analysis only 2. updated Lagrangian		
NPAR(4) Element birth and death option 0. elements are active throughout solution 1. elements become only active at the time of birth 2. elements become inactive at the time of death		
NPAR(5) Element type code 0. two-dimensional action 1. three-dimensional action		
NPAR(6) Skew coordinate system reference indicator 0. all element nodes use the global system only		

TAPE 1 Element Group: Beam Elements (Continued)

Description	Variable	Dimension
1. some element node d.o.f. are referred to a skew coordinate system		
NPAR(7) Section identification flag 0. default set to 1 1. rectangular section 2. pipe section		
NPAR(9) Numerical integration order for r-direction		
NPAR(10) Numberical integration order for s-direction		
NPAR(11) Numerical integration order for t-(or θ) direction		
NPAR(12) Number of end release tables		
NPAR(13) Number of stress output location tables EQ.-1 print and save nodal forces EQ.0 print and save stresses at all integration points GT.0 print and save stresses at selected integration points as defined in the stress output tables		

TAPE 1 Element Group: Beam Elements (Continued)

Description	Variable	Dimension
NPAR(14) Maximum number of stress output locations in each table		
NPAR(15) Material model number 0. default set to 1 1. linear elastic 2. elastic-plastic		
NPAR(16) Number of different sets of section/material properties		
Young's modulus	E	NPAR(16) IF NPAR(3)=0
Shear modulus	G	NPAR(16) IF NPAR(3)=0
Mass density	DEN	NPAR(16) IF NPAR(3)=0
Second moment of area about R-axis	XI	NPAR(16) IF NPAR(3)=0
Second moment of area about S-axis	YI	NPAR(16) IF NPAR(3)=0
Second moment of area about T-axis	LI	NPAR(16) IF NPAR(3)=0
Normal + shear section area	AREA	NPAR(16) IF NPAR(3)=0
Element nodal coordinates	XYZ	3*NPAR(16) IF NPAR(3)=0
Nodal D.O.F. number	LM	9*NPAR(2)
Stress printing flag	IPS	12*NPAR(2)
Material set number	MATP	NPAR(2)
Material constants	PROP	NFAC*NPAR(17)*NPAR(16) NFAC=1 IF NPAR(3)=0 then NFAC=0
NPAR(15): 1. Young's modulus, E Poisson's ratio, ν		

TAPE 1 Element Group: Beam Elements (Continued)

Description	Variable	Dimension
First section dimension, DO Second section dimension, DI 2. Young's modulus, E Poisson's ratio, ν First section dimension, DO Second section dimension, DI Initial yield stress, σ_y Strain hardening modulus, E_T		
Flag for transverse shear effects	ISHEAR	NFAC*NPAR(16)
Working array	WA	NFAC*NPAR(9)*NPAR(10)*NPAR(11)*11*NPAR(2)
Stress output location tables	ITABLE	LL*NFAC*NPAR(13)

Stress output at 1st selected integration point		LL=NPAR(14)/16
		LLL=NPAR(14)-LL*16
		IF(LLLGT.0)LL=LL+1
		LL=LL*16

...		
Stress output at 16th selected integration point		
Stress output at 17th selected integration point		
...		
Stress output at NPAR(14)th selected integration point		
Gauss elimination coefficients	SR	(6+48*NPAR(5))*NFAC*NPAR(2)
Element expiry time array	ETIMV	MM*NPAR(2) IF NPAR(14)>1 MM=1

TAPE 1 Element Group: Beam Elements (Continued)

Description	Variable	Dimension
Element displacement vector	EDISP	12*MM*NPAR(2) IF (NPAR(14)>0) MM=1
Element release table	IMOMNT	6*NPAR(12)
Displacement at previous step	PDISP	12*NPAR(2)
Element rotational angle between local to global system	GAMA	NPAR(2)
Nodal skew coordinate flag	ISKEW	MM*2*NPAR(2) IF(NPAR(6)>0)MM=1

Element condensed Gauss elimination coefficients	SREL	36*MM*NFAC*NPAR(2)
		MM=1
		IF(NPAR(12)=0) MM=0

Element recovered displacement correction	RERIT	8*MM*NPAR(2)
		MM=1
		IF(NPAR(3)=0)MM=0

TAPE 1 Element Group: Isoparametric Beam Elements

Description	Variable	Dimension
Element group control information	NPAR	20
NPAR:		
NPAR(1)= 5		
NPAR(2) Number of ISO/BEAM elements in this group		
NPAR(3) Type of analysis 0. linear analysis 1. material non-linear analysis only 2. total Lagrangian formulation		
NPAR(4) Element death option 0. elements are active throughout solution 1. elements become only active at the time of birth 2. elements become inactive at the time of death		
NPAR(5) Element type code 0. default set to 1 1. rectangular cross-section		
NPAR(6) Skew coordinate system reference indicator 0. all element nodes use the global system only 1. some elements refer to skew systems		

TAPE 1 Element Group: Isoparametric Beam Elements (Continued)

Description	Variable	Dimension
NPAR(7) Maximum number of nodes used to describe any one element		
NPAR(9) Number of integration points along centroidal axis of element GT.0 Gauss integration LT.0 closed Newton-Cotes EQ.0 default set to NPAR(7)		
NPAR(10) Numberical integration points on element cross section(s-direction)		
NPAR(11) Number of integration points on element cross section (t-direction)		
NPAR(13) Number of stress output tables LT.0 force and moment output at element nodes EQ.0 stress output at all integration points GE.0 number of stress output tables defining selective output at integration points		
NPAR(14) Maximum number of stress output location in each stress output table		

TAPE 1 Element Group: Isoparametric Beam Elements (Continued)

Description	Variable	Dimension
NPAR(15) Material model number 0. default set to 1 1. linear elastic 1. elastic-plastic (isotropic) 3. elastic-plastic (kinematic)		
NPAR(16) Number of different sets of section/ material properties		
Element nodal coordinates	XYZ	3*NPAR(7)*NPAR(2)
Element auxiliary nodal coordinates	CENTER	3*NPAR(2)
Nodal D.O.F. number	LM	6*NPAR(7)*NPAR(2)
Element number of nodes	IELT	NPAR(2)
Material property set number	MATP	NPAR(2)
Material constants	PROP	NPAR(17)*NPAR(2)
NPAR(15): 1. Young's modulus, E Poisson's ratio, ν 2. Young's modulus, E Poisson's ratio, ν yield stress in simple tension, σ_y strain hardening modulus, E_T 3. Young's modulus, E Poisson's ratio, ν		

Description	Variable	Dimension
yield stress in simple tension, σ_y		
strain hardening modulus, E_T		
Mass density set number	DEN	NPAR(16)
Element expiry time array	ETIMV	MM*NPAR(2) IF(NPAR14)=1)MM=1
Element birth time nodal = coordinates	EDISOL	MM*6*NPAR(7)*NPAR(2) IF(NPAR(4)>0 MM=1
Stress output printing flag	IPST	NPAR(2)

Stress output tables	ISTAB	MM*NPAR(13)*MPT
		IF(NPAR(14)>)MPT=NPAR(14)+1
		IF(NPAR(13)>0)MM=1

Centroidal axis integration point number of first stress output location GT.0 and LE.NPAR(9)		
S-axis integration point number of first stress output location GT.0 and LE.NPAR(10)		
T-axis integration point number of first stress output location GT.0 and LE.NPAR(11)		
Centroidal axis integration point number of second sress output location		
S-axis integration point number of second stress output location		

TAPE 1 Element Group: Isoparametric Beam Elements (Continued)

Description	Variable	Dimension
T-axis integration point number of second stress output location		
...		
...		
...		

Working array	WA	NPAR(18)*IABS(NPAR(9)*
		NPAR(10)*NPAR(11))*NPAR(2)

Skew coordinates flag	ISKEW	NM*3NPAR(7)*NPAR(2) IF(NPAR(6)>0)MM=1
Element section dimension	SECT	NSCON(NPAR(5))*NPAR(16)
Element Euler angle	EULER	MM*3*NPAR(7)*NPAR(2) IF(NPAR(3)=2)THEN MM=1
Element rotation	ROTOLD	MM*3*NPAR(7)*NPAR(2)
Not used	IELS	NPAR(2)
Gauss elimination coefficients	SR	(2*6NPAR(7))*NPAR(2)
Element total displacements	EDIS	MM*6*NPAR(7)*NPAR(2) IF NPAR(3)>1 THEN MM=1
Element total torsinoal Ritz function displacements	RITZ	MM*NPAR(2)
Element correction to recovered Ritz function displacements	RERIT	5*MM*NPAR(2)

TAPE 1 Element Group: Plate/Shell Element

Description	Variable	Dimension
Element group control information	NPAR	20

NPAR:

NPAR(1)= 6

NPAR(2) Number of PLATE/SHELL elements in this group

NPAR(3) Code indicating type of nonlinear analysis
- 0. linear analysis
- 1. material nonlinear analysis
- 2. updated Lagrangian

NPAR(4) Element birth and death option
- 0. elements are active throughout solution
- 1. elements become only active at the time of birth
- 2. elements become inactive at the time of death

NPAR(6) Skew coordinate system reference indicator
- 0. all element nodes use the global system only
- 1. some element node d.o.f. are referred to a skew coordinate system

NPAR(11) Integration scheme used for stiffness calculation (in nonlinear analysis)

TAPE 1 Element Group: Plate/Shell Element (Continued)

Description	Variable	Dimension
GE.1 and LE.4 default set to 2 EQ.1 1-point (centroid) EQ.2 3-point (interior) EQ.3 3-point (mid-side) EQ.4 7-point (interior)		
NPAR(13) Number of stress resultant output location tables GE.0 and LE.10 EQ.0 output forces/ mements at integration points		
NPAR(15) Material model number GE.1 and LE.3 defult set to 1 1. isotropic linear elastic 2. orthotropic linear elastic 3. elastic-plastic (Ilyushin, isotropic hardening)		
NPAR(16) Number of different sets of material properties		
Mass density set number	DEN	NPAR(16)
Nodal D.O.F. number	LM	18*NPAR(2)
Element nodal coordinates	XYZ	9*NPAR(2)
Material property set number	MATP	NPAR(2)
Element thickness	THICI	NPAR(2)
Element stress printing flag	IPS	NPAR(2)

TAPE 1 Element Group: Plate/Shell Element (Continued)

Description	Variable	Dimension
Element expiry time array	ETIMV	MM*NPAR(2) IF(NPAR14)>0)MM=1
Element birth nodal coordinates	EDISB	MOPT*18*NPAR(2) IF(NPAR(4)>)MOPT=1
Material constants	PROP	NMCON(NPAR(15))*NPAR(16)
NPAR(15):		
1. Young's modulus, E Poisson's ratio, ν		
2. Modulus E_{aa} Modulus E_{ab} Modulus E_{bb} Modulus G_{ab}		
3. Young's modulus E Poisson's ratio, ν Yield stress in simple tension, σ_y Strain hardening modulus, E_T Ilyushin factor, γ default set to 0.0		
Working array	WA	IDWAS(NPAR(15))**NINTV (NPAR(10))*NPAR(2)
Stress resultant output location tables	ITABLE	NPAR(13)*7
Moment output location 1		
Moment output location 2		
Moment output location 3		
Moment output location 4		

TAPE 1 Element Group: Plate/Shell Element (Continued)

Description	Variable	Dimension
Moment output location 5		
Moment output location 6		
Moment output location 7		
Skew coordinates flag	ISKEW	MOPT*NPAR(2)*3 IF(NPAR(6)>0) Then MOPT=1
Orthotropic property direction array	BETA	MOPT*NPAR(2) IF(NPAR(15)=1) Then MOPT=1
Element previous time step displacements	PDIS	MOPT*NPAR(2)*18 IF(NPAR(4)>2 OR NPAR(15)>3) Then MOPT=1
Element moments at integration points	ELM	3*NINTV(NPAR(10))*NPAR(2)

TAPE 1 Element Group: Shell Elements

Description	Variable	Dimension
Element group control information	NPAR	20

NPAR:

NPAR(1)= 7

NPAR(2) Number of SHELL elements in this group

NPAR(3) Flag indicating type of nonlinear analysis
- 0. linear analysis
- 1. material nonlinear analysis only
- 2. total Lagrangian

NPAR(4) Element birth and death option
- 0. elements are active throughout solution
- 1. elements become only active at the time of birth
- 2. elements become inactive at the time of death

NPAR(5) Flag indicating the coordinate system
- 0. global Cartesian coordinate system
- 1. shell coordinate directions

NPAR(6) Skew coordinate system reference indicator

TAPE 1 Element Group: Shell Elements (Continued)

Description	Variable	Dimension
0. all element nodes use the global system only 1. some element node d.o.f. are referred to a skew coordinate system		
NPAR(7) Maximum number of nodes used to describe any one element		
NPAR(8) Maximum number of total nodes used to describe any one element		
NPAR(9) Maximum number of nodes in the r or s-directions		
NPAR(10) Gauss integration order in (r)-direction, LE.4		
NPAR(11) Gauss integration order in (s)-direction		
NPAR(12) Gauss integration order in (t)-direction (through element thickness)		
NPAR(13) Number of stress output location tables		
NPAR(14) Number of shell thickness tables		

TAPE 1 Element Group: Shell Elements (Continued)

Description	Variable	Dimension
NPAR(15) Material model number GE.0 and LE.2 0. default set to 1 1. linear elastic 2. elastic-plastic (von Mises, isotropic hardening)		
NPAR(16) Number of different sets of material properties		
Nodal D.O.F. number	LM	(3*NPAR(8)+2*NPAR(8))*NPAR(2)
Element nodal coordinates	XYZ	(3*NPAR(8)+2*NPAR(8))*NPAR(2)
Element number of nodes	IELTD	NPAR(2)
Element number of mid-surface nodes	IELTP	NPAR(2)
Element stress printing flag	IPST	NPAR(2)
Material property set number	MATP	NPAR(2)
Similar stiffness and mass matrices indicator	IREUSE	NPAR(2)
Optional node array	NDOPT	NPAR(8)*NPAR(2)
Element expiry time array	ETIMV	NPAR(2)
Element birth time nodal coordinates	EDISB	3*NPAR(8)*NPAR(2)
Mass density	DEN	NPAR(16)
Material constants	PROP	NPAR(17)*NPAR(16)
NPAR(15): 1. Young's modulus, E		

Description	Variable	Dimension
Poisson's ratio, ν shear factors, K 2. Young's modulus, E Poisson's ratio, ν yield stress in simple tension, σ_y strain hardening modulus, E_T		

Working array	WA	NPAR(20)*NPT*NPAR(2)
		where
		NPT=NNRS*NPAR(12)
		NNRS=NPAR(10)*NPAR(11)
		IF(NNRS=2 or NNRS=3)NNRS=4
		IF(NNRS=6)NNRS=7
		IF(NNRS=12)NNRS=13

Stress output location tables	ITABLE	16*NPAR(16)
ITABLE(N,1) Stress output location 1		
ITABLE(N,2) Stress output location 2		
ITABLE(N,3) ...		
ITABLE(N,4)		
ITABLE(N,5)		
ITABLE(N,6)		
ITABLE(N,7)		
ITABLE(N,8)		
ITABLE(N,9)		
ITABLE(N,10)		
ITABLE(N,11)		

Description	Variable	Dimension
ITABLE(N,12)		
ITABLE(N,13)		
ITABLE(N,14)		
ITABLE(N,15)		
ITABLE(N,16) Stress output location 16		
Thickness tables	THICK	NPAR(14)*NPAR(8)
Thickness of the shell at 1st mid-surface node GT.0		
Thickness of the shell at 2nd mid-surface node EQ.0 default set to THICK(N,1)		
...		
Thickness of the shell at 8th mid-surface node EQ.0 default set to THICK(N,1)		
IF NPAR(8)>0		
Thickness of the shell at 9th mid-surface node EQ.0 default set to THICK(N,1)		
. . .		
Thickness of the shell at NPAR(8)th mid-surface node EQ.0 default set to THICK(N,1)		
Skew coordinates flag	ISKEW	NPAR(2)*NPAR(7)
Element thickness table identifiers	NTHT	NPAR(2)
Initial (nodal) normal vector	VNI	3*NPAR(8)
(Nodal) normal vector at time t	VNT	3*NPAR(8)

TAPE 1 Element Group: Shell Elements (Continued)

Description	Variable	Dimension
(Nodal) vector v_1 at time t	V1	3*NPAR(8)
Global normal-number of mid-surface nodes	NORGOL	NPAR(8)*NPAR(2)
Element base shape (triangle or quadrilateral) identifiers	ISHAP	NPAR(2)

TAPE 1 Element Group: 2/D Fuild Elements

Description	Variable	Dimension
Element group control information	NPAR	20

NPAR:

NPAR(1)= 11

NPAR(2) Number of 2/D FLUID elements in this group

NPAR(3) Code indicating type of non-linear analysis
- 0. linear analysis
- 1. updated Lagrangian

NPAR(4) Element birth and death option
- 0. elements are active throughout solution
- 1. elements become only active at the time of birth
- 2. elements become inactive at the time of death

NPAR(5) Element type code
- 0. axisymmetric
- 1. plane

NPAR(6) Skew coordinate system reference indicator
- 0. all element nodes use the global system only
- 1. some element node d.o.f. are referred to a skew coordinate system

TAPE 1 Element Group: 2/D Fuild Elements (Continued)

Description	Variable	Dimension
NPAR(7) Maximum number of nodes used to describe any one element		
NPAR(10) Numerical integration order to be used in Gauss quadrature formula		
NPAR(15) Material model number 0. default set to 1 1. inviscid, compressible fluid with constant bulk modulus		
NPAR(16) Number of different sets of material properties		
NPAR(17) Number of constants per property set		
Nodal D.O.F. number	LM	2*NPAR(7)*NPAR(2)
Element nodal coordinates	YZ	2*NPAR(7)*NPAR(2)
Element number of nodes	IELT	NPAR(2)
Element stress printing flag	IPST	NPAR(2)
Element material property set number	MATP	NPAR(2)
Mass density	DEN	NPAR(16)
Material constants 1. Bulk modulus, K	PROP	NPAR(17)*NPAR(16)
Working array	WA	NPAR(20)*NPAR(10)**2*NPAR(2)+ NDWS(NPAR(15))*NPAR(7)*NPAR(2)
Element mid-side nodes location array	NOD5	(2*NPAR(7)-1)*NPAR(2)

Description	Variable	Dimension
Element expiry time array	ETIMV	MM*NPAR(2) IF(NPAR(4)>0) THEN MM=1
Element birth time nodal coordinates	EDISB	MM*NPAR(2)*2*NPAR(7) IF(NPAR(6)>0 THEN MM=1
Skew coordinates flag	ISKEW	MM*NPAR(2)*2*NPAR(7) IF(NPAR(6)>0 THEN MM=1
Element degenerated flag	ISO	NPAR(2)

TAPE 1 Element Group: 3/D Fuild Elements

Description	Variable	Dimension
Element group control information	NPAR	20

NPAR:

NPAR(1)= 12

NPAR(2) Number of 3/D FLUID elements in this group

NPAR(3) Flag indicating type of non-linear analysis
- 0. linear analysis
- 1. updated Lagrangian

NPAR(4) Element birth and death option
- 0. elements are active throughout solution
- 1. elements become only active at the time of birth
- 2. elements become inactive at the time of death

NPAR(6) Skew coordinate system reference indicator
- 0. all element nodes use the global system only
- 1. some element node d.o.f. are referred to a skew coordinate system

TAPE 1 Element Group: 3/D Fuild Elements (Continued)

Description	Variable	Dimension
NPAR(7) Maximum number of nodes used to describe any one element		
NPAR(10) Numerical integration order to be used in Gauss quadrature formulae for r-s plane		
NPAR(11) Numerical integration order to be used in Gauss quadrature formula for t-direction		
NPAR(15) Material model number 0. default set to 1 1. inviscid, compressible fluid with constant bulk modulus		
NPAR(16) Number of different sets of material properties		
Nodal D.O.F. number	LM	3*NPAR(7)*NPAR(2)
Element nodal coordinates	XYZ	3*NPAR(7)*NPAR(2)
Element number of nodes	IELTD	NPAR(2)
Element geometry number of nodes	IELTX	NPAR(2)
Element stress printing flag	IPST	NPAR(2)
Element material property set number	MATP	NPAR(2)
Element mid-side nodes location array	NOD9	(NPAR(7)-1)*NPAR(2)
Similar stiffness and mass matrices indicator	IREUSE	NPAR(2)

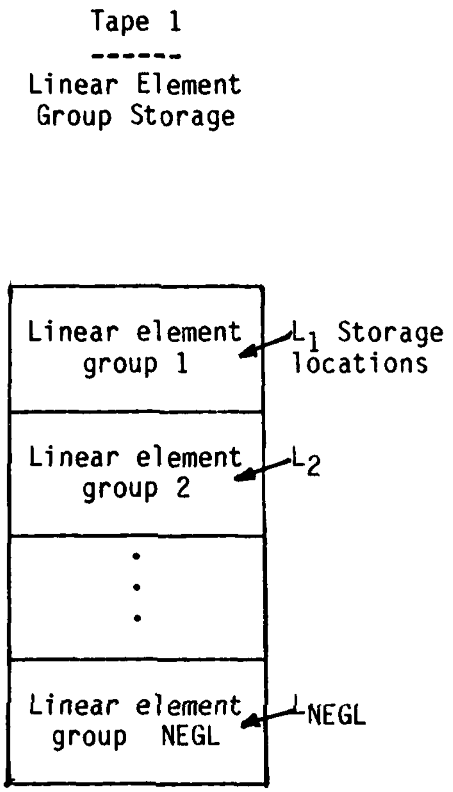
TAPE 1 Element Group: 3/D Fuild Elements (Continued)

Description	Variable	Dimension
Mass density	DEN	NPAR(16)
Material constants 1. Bulk modulus, K	PROP	NPAR(17)*NPAR(16)

Working array	WA	NDWS(NPAR(15))*
		NPAR(10)**2*NPAR(2)

Element expiry time array	ETIMV	MM*NPAR(2) IF(NPAR(4)>0 THEN MM=1
Element birth time nodal coordinates	EDISB	NPAR(2)*NPAR(7)
Skew coordinates flag	ISKEW	NPAR(2)*NPAR(7)
Element degenerated flag	ISO	NPAR(8)*NPAR(2)

Comment: storage organization for Tape 1 is shown in Fig. 3.1.



L_1, NL_1, L_2, NL_2, ·····, L_{NEGL}, NL_{NEGNL} <

MAXEST = MIDEST = length of array needed for element group data.

Figure 3.1 Auxilary Storage Organization for Linear Element Group Information (Tape 1)

3.5.2 Tape 2

Specifications

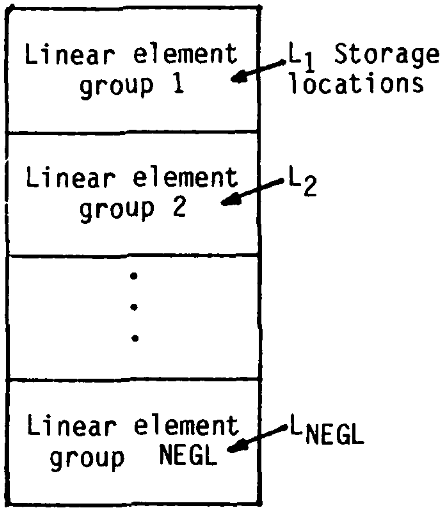
- Random access file
- Stores nonlinear element group data

Comment:

Tape 2 is similar to Tape 1, except that it is a random access file for nonlinear element group information NEGNL>0. Details of element group data are the same as for Tape 1. Storage organization for Tape 2 is shown in Fig. 3.2.

Tape 2

(Random access unit)
Nonlinear Element
Group Storage



Both reading and
writing during time
integration

Figure 3.2 Auxilary Storage Organization for Nonlinear Element Group Information (Tape 2)

3.5.3 Tape 3

Specifications:

- Sequential access file
- Stores externally applied loads

Comment:

Program ADINA stores load vector information in 1-D array. Dimension of the array is NEQ, where

NEQ = number of equations (Total number of structural D.O.F.)

Description	Variable	Dimension
Externally applied loads	R	NEQ = number of equations

•
•
•
Repeat NSTE times

NSTE = number o solution time steps

(see master control card 1 in ADINA)

3.5.4 Tape 4

Specifications:

- *Sequential access file*
- Stores the linear stiffness matrix when NEGL ≠ 0 or NSUBST ≠ 0 only. (see master control card 1 in ADINA)

Comment:

Program ADINA stores linear stiffness matrix one time. Program does not store addresses of the diagnonal stiffness elements.

Description	Variable	Dimension
Elements of linear stiffness matrix under the skyline	AA	ISTOH

•
•
•
Repeat NBLOCK times

NBLOCK = number of blocks

ISTOH = storage used under the skyline

3.5.5 Tape 5

Specifications:

- Initial input file (It is ADINA•IN)

3.5.6 Tape 6

Specifications

- Output file (It is ADINA•OUT)

3.5.7 Tape 7

Specifications:

- Sequential access file
- Stores effective liner stiffness matrix in direct time integration and used as a scratch file during mode superpostion analysis

Comment:

Program ADINA stores effective linear stiffness matrix only once. It does not store addresses of the diagonal effective stiffness elements.

Description	Variable	Dimension
Elements of linear effective stiffness matrix under the skyline	AA	ISTOH

•

•

•

Repeat NBLOCK times

NBLOCK = number of blocks

ISTOH = storage used under the skyline

Tape 7 is used as a scratch file during mode superposition analysis. First it stores damping factors XSI as:

Description	Variable	Dimension
Damping factors	XSI	NMODES = number of nodal damping factors

Then Tape 7 is rewound and stores ϕ, where ϕ is the mode shape vector and is determined from the solution of eigenproblem:

$$K\phi = \omega^2 M\phi$$

where

K = stiffness matrix

ω = natural frequency (rad/sec)

M = mass matrix

3.5.8 Tape 8

Specifications:

- Sequential access file
- Stores

(1) ID array (D.O.F. identification)
(2) During input:
initial displacements, velocities, and accelerations
On output:
final displacements, velocities, and acceleration vectors and nonlinear element group data for a restart job.

Comment:

ID array is stored first, then during input phase, initial displacements, velocities, and accelertions are stored. Nonlinear element group data is not stored if NSUBST = number of substrctures = 0 or linear analysis. Final displacements, velocities and accelerations are stored according to the different phases.

Description	Variable	Dimension
Structural D.O.F. identification	ID	NDOF*NUMNP NDOF = computed maximum number of d.o.f. for each node NUNMP = total number of nodal points
Mid-surface normals	FMIDSS	3*MAXMSS MAXMSS = total number of mid-surface normals (for nonlinear analysis)
Length array needed for element group data	MIDEST	scalar Only for a nonlinear analysis
Element group data (see Tape 2)	EE	MIDEST
	. . . Repeat NEGNL times	
Static or dynamic status	ISTAT	scalar ISTATO=0 static anaysis ISTAT>0 dynamic analysis
Time step increment	DT	scalar
Displacements at nodal points	DISP	NEQ NEQ=number of equations
Velocities at nodal point (for dynamic analysis)	VEL	NEQ
Acceleration at nodal points (for dynamic analysis)	ACC	NEQ

3.5.9 Tape 9

Specifications:

- Sequential access file
- Stores mode shapes and circular frequencies (if frequency solution was requested); also used as a scratch file during equilibrium iterations.

Comment:

This tape has been used as a scratch file to store normal vectors (FMIDSS) and v_1 vectors (FMVI).

Description	Variable	Dimension
Eigenvectors	PHI	NEQ NEQ=number of equation frequencies
⋮ Repeat NFREQ times		
Eigenvalues	ROOT	NFREQ NFREQ=number of frequencies and mode shapes to be calculated

3.5.10 Tape 10

Specifications:

- Random access file
- Stores D-L (diagonal and lower triangle) factors of effective linear or nonlinear stiffness matrix in time integration

Comment:

This is a random access file. It sotres the D-L information. The length of each record is 3000 words. If the length of a block is more than 3000 words, next record is allocated to the remainder of that record.

Description	Variable	Dimension
Factors of effective linear or nonlinear stiffness matrix	DL	ISTOH ISTOH = maximum block length

•
•
•

Repeat NBLOCK times

3.5.11 Tape 11

Specifications:

- Sequential access file
- Stores

(1) Mass matrix (consistent mass if IMASS = 2)
IMASS = flag indicating static or dynamic analysis
(2) Damping factor

Comment:

On this tape lumped mass is stored once in a block, but consistent mass depends on the number of Block = NBLOCK.

For lumped mass:

Description	Variable	Dimension
LUMPED MASS	WLUMPED	NEQ
Concentrated dampers	Damp	NEQ = number of equations

For consistent mass:

Description	Variable	Dimension
Consistent mass	WCONSIS	ISTOH ISTOH = maximum block length

•
•
•
Repeat NBLOCK times

Description	Variable	Dimension
Concentrated dampers	Damp	NEQ NEQ = number of equations

3.5.12 Tape 12

Specifications:

- Sequential access file
- Initially used as scratch file in load calculations. It stores the effective nonlinear stiffness matrix in time integration-or-the nonlinear stiffness matrix for eigensystem solution.

Comment:

Information on this tape is based on the requested job in analysis. If NSTE = 0 and frequency analysis is asked for, updated linear stiffness (nonlinear stiffness matrix) is stored, and if NSTE ≠ 0 and nonlinear analysis is asked for, effective nonlinear stiffness matrix in time integration is stored.

Description	Variable	Dimension
Effective nonlinear or just nonlinear stiffness matrix	AA	ISTOH ISTOH = maximum block length

•
•
•
Repeat NBLOCK times

NBLOCK = number of blocks

3.5.13 Tape 13

Specifications:

- Sequential access file
- Stores initially line function values and prescribed displacement data during time integration

Comment:

Description	Variable	Dimension
Value of line function at t = 0	RGST	NTFN NTFN = number of time functions
Interpolated value of time function at each step	RG	NTFN*NSTE NSTE = number of solution time steps
Number of points used to input the related time function RV	NPTS	scalar
Function value at each point	RV	NPTS*NTFN
Related time to RV function value	TIMV	NPTS*NTFN

If number of prescribed displacement is greater than zero then following data are stored on tape.

Description	Variable	Dimension
Prescribed displacements	R	NPDIS NPDIS = number of prescribed displacements

.
.
.

Repeat NSTE times

NSTE = number of solution time steps

3.5.14 Tape 14

Specifications:

- Sequential access file
- Stores substructures data

Comment:

Suhstructure element group data are stored on Tape 1. Substructures use linear element group data, and as a result, Tape 2 has no information related to substructures element group data.

Description	Variable	Dimension
Number of time the substructure is used	NTUSE	scalar
Number of element group used to define the substructure	NEGLS	scalar
Number of nodal point in the substructure	NUMNPS	scalar
Number of nodes to be condensed for the substructure	NODCON	scalar
No of nodes to be retained for the substructure	NODRET	scalar
X,Y,Z, translation and rotation code	IDOFS	6
Maximum nodal D.O.F. for the substructure	NDOFS	scalar
Addresses of diagonal substructure stiffness matrix	IA	NEQS NEQS = number of equation for the substructure
Number of columns per block	IA	NBLOCS NBLOCS = number of blocks for the substructure

Description	Variable	Dimension
Number of blocks for the substructure	IA	NBLOCS
Number of XYZ coordinates system use for the reused substructure	NXYZ	scalar
Identical loading for the reused-substructure	LREUSE	scalar
Number of concentrated load for the substructure	NLOADS	scalar
Total number of 2-D pressure load for the reused-substructure	NPR2S	scalar
Total number of 3-D pressure load for the reused-substructure	NPR3S	scalar
Total number of 2-node beam pressure load for the reused-substructure	NPMBS	scalar
Total number of ISO/beam pressure load for the reused-substructure	NDIDBS	scalar
Total number of plate shell pressure load for the reused-substructure	NPPLS	scalar
Total number of shell pressure load for the reused-substructure	NPSHS	scalar
---	NOD3S	scalar
Direction ratio for the substructure	DIRNUM	9
Total number of d.o.f. for the substructure	ND	scalar

Description	Variable	Dimension
Nodal D.O.F. number for the reused substructure (same as LM)	LMS	ND
Print out directive indicator for the reused-substructure	ISC	scalar ISC = 0 no print out ISC ≠ 0 print out
Number of itme-step blocks for nodal and element associated print-out	NSPRIB	scalar
Number of displacement block print-out	NSPB	scalar
Block definition of print-out time steps for the reused-susbstructure	ISPRIB	3*NSPRIB
Block definition of nodal quantities print-out print-out for the reused substructure	ISPNOD	3*NSPB

.
.
.

Repeat NTUSE times
loop 2

- - - - - - - - - - - -

.
.
.

Repeat NSUBST times
loop 1

NTUSE = associated number of times for the substructure

NSUBST = number of independent substructure

3.5.15 Tape 15

Specifications:

- Sequential access file
- Stores load vector values for each time function, substructure ID array, ID array and master structure nodal responses (displacements at all time steps

Comment:

Description	Variable	Dimension
Value of time function at t = 0	RGST	NTFN NTFN = *number of time functions*
Interpolated value of time function at each step	RG	NTFN*NSTE NSTE = number of solution time steps
Number of points used to input the related time function RV	NPTS	scalar
Function value at each point	RV	NPTS*NTFN
Related time to RV function vector	TIMV	NPTS*NTFN
Substructure D.O.F. identification	ID	NDOFS*NUMNPS NDOFS = maximum nodal D.O.F. for the substructure NUMNPS = number of nodal points in the substructure
Skew coordinates system for each node in the substructure	NODSYS	NUMNPS
X-Coordinates for the substructure	X	NUMNPS
Y-Coordinates for the substructure	Y	NUMNPS

Description	Variable	Dimension
Z-Coordinates for the substructure	Z	NUMNPS

•
•
•

Repeat NSUBST time

NSUBST = number of independent substructure

Description	Variable	Dimension
Master nodal displacement	DISP	NEQ+NDISCE NEQ = number of equations NDISCE = number of displacements constraint equations

•
•
•

Repeat NSTE times

NSTE = number of solution time steps

3.5.16 Tape 16

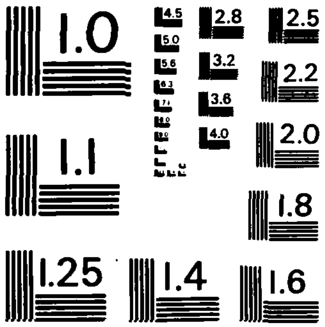
Specifications:

- Random access file
- Stores substructural factorized stiffness matrices

Comment:

Substructural stiffness matrices are calculated and decomposed only once because only linear element groups are used in substructing.

AD-A162 355 DATABASE DESIGN FOR STRUCTURAL ANALYSIS AND DESIGN 2/4
OPTIMIZATION(U) IOWA UNIV IOWA CITY APPLIED-OPTIMAL
DESIGN LAB J S ARORA ET AL. OCT 84 CAD-SS-84-22
UNCLASSIFIED AFOSR-TR-85-1079 F/G 9/2 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Description	Variable	Dimension
Factorized stiffness matrice for the substructure	SUBSTIFF	ISTOSH ISTOSH = maximum block length for the substructure

•
•
•
Repeat NBLOCS times

- - - - - - - - - - - -

•
•
•
Repeat NSUBST times

NBLOCS = number of blocks for the substructures

NSUBST = number of independent substructures

3.5.17 Tape 17

Specifications:

- Random access file

- Stores externally applied loads for all time steps, and substructure nodal responses (displacements) for static analysis. In dynamic analysis, it stores externally applied loads at all time steps and nodal loads at all time steps for each substructure and reused-substructure.

Comment:

Tape 17 is used as a temporary file for nodal loads in static analysis.

Description	Variable	Dimension
External nodal loads	EXLOAD	NEQ NEQ = number of equations of the master structure

•

•

•

Repeat NSTE times

NSTE = *number of solution time steps*

Description	Variable	Dimension
Condensed nodal displacements (internal nodes)	CODISP	NEQC NEQC = number of condensed equations for the substructure
(In a static analysis)		
Substructure load (condensed and boundary nodal loads)	SUBLOAD	NEQS NEQS = number of equations for the substructure

•

•

Repeat NSTE times

- - - - - - - - - - -

•

•

Repeat NTUSE times

- - - - - - - - - - - - - - -

•

•

Repeat NSUBST times

- - - - - - - - - - - - - - - - - - -

NSTE = number of solution time steps

NTUSE = number of times the substructure is used

NSUBST = number of independent substructure

3.5.18 Tape 18

Specifications:

- Sequential access file
- Stores data in BFGS iteration and vectors input to subspace iteration, also temporarily stores reduced substructure stiffness

Comment:

Data in BFGS means out of balance loads.

Description	Variable	Dimension
Out of balance load in BFGS iteration	RE	NEQ NEQ = number of equations

3.5.19 Tape 19

Specifications:

- Sequential access file
- Stores vectors in subspace iteration

Comment:

Tape 19 stores eigenvectors if IACCN = flag for usage of acceleration schemes ≠ 0.

Description	Variable	Dimension
Eigenvectors in subspace iteration	EIGVEC	NEQ NEQ = number of equations

.
.
.
Repeat NQ times

NQ = number of iteration used in subspace iteration solution if IESTYP = 1, IESTYP = 0 default set to Min(2*NFREQ,NFREQ+8)

4.5.20 Tape 22

Specifications:

- Sequential access file
- Stores load vector during equilibrium equation

Comment:

No informations are available on this tape if IMODES > 0. In this tape vector R^* for the solution of $K\Delta U = R^*$ is stored. (See Klaus jurgen Bath: finite element procedures in engineering analysis).

where R^* = Unbalanced load vector during equilibrium equation

ΔU = Incremental displacement

K = Tangent stiffness matrix

Description	Variable	Dimension
Load vector during equilibrium equation	RSTAR	NEQ NEQ = number of equation in master system

3.5.21 Tape 23

Specifications:

- Sequential access file
- Stores substructure nodal responses (displacements) at all time, steps, also temporarily stores concentrated masses and dampers

Comment:

Substructure nodal responses.

Description	Variable	Dimension
Displacement vector of the substructure	DISP	NEQS NEQS = number of equations for the substructure
Velocity vectors of the substructure (In dynamic analysis)	VEL	NEQS
Acceleration vectors of the substructure in dynamic analysis	ACC	NEQS

⋮

Repeat NTUSE times

- - - - - - - - - - - -

⋮

Repeat NSUBST times

- - - - - - - - - - - - - - - -

⋮

Repeat NSTE times

NTUSE = number of times for the substructure

NSUBST = number of independent substructures

NSTE = number of solution time steps

Concentrated masses and dampers on Tape 23 are stored temporarily as:

Description	Variable	Dimension
Concentrated nodal masses	CONMASS	NEQ NEQ = number of equation for the master structure
Concentrated nodal dampers	CONDAMP	NEQ

3.5.22 Tape 50

Specifications:

- Initial input file in which comment cards are included in the input stream

Comment:

The option of using comment cards in the input stream of the data cards is directly available for a CDC computer. Additional verification may be needed for other systems. Presently, for prime computer, it is not available, no information is accesible on Tape 50.

3.5.23 Tape 56

Specifications:

- Sequential access file
- Stores nodal point temperature in NSTE+1 (NSTE = number of solution time steps) records. 1st record is allocated to the temperature at time 0, and 2nd record devoted to temperature at time Δt and so on.

Comment:

If ITP96 = 1, temperatures are reused from Tape 56. (See master control card in ADINA).

Description	Variable	Dimension
Time of solution start	TSTART	scalar
Temperature at start time	TEMP	NUMNP NUMNP = number of nodal points
Time of temperature (t)	TIME	scalar
Temperature at time t		NUMNP NUMNP = number of nodal points

•
•
•

Repeat NSTE times

NSTE = number of solution time steps

3.5.24 Tape 59

Specifications:

- Sequential access file and formatted
- Stores preprocessed input data (if used)

Comment:

Tape 59 is used as a data file for preprocessor, program ADINA reads the required informations from this file if INPORT > 1(INPORT = control parameter for reading nodal and eliment information from preprocessor tape).

Comment:

If INPORT > 0 the following data is read by the program ADINA from unit 59 and therefore should not be input in the card deck.

(1) Nodal point data described in Section V.3 (See AE81-1 User's Manual)

(2) The ID array (identification equation number) with equation numbers associated with all active degrees of freedom if INPORT = 2.

(3) Element data cards described in Section XI to XXX (See AE81-1 User's Manual).

(4) Substructure nodes and elements (see XXXI.26, AE81-1 Users' Manual).

Description	Variable	Dimension
Symbol describing the coordinate system for this node	IT	character
Node number	N	scalar
Print suppersion flag	JPR	character
X,Y,Z translation and rotation boundary code	IDT	6
X-nodal coordinate	X	NUMNP
Y-nodal coordinate	Y	NUMNP
Z-nodal coordinate	Z	NUMNP
Node number increment for node data generation	KN	scalar
Skew coordinate system for this node	NRST	scalar
Mid-surface vector set for this node	MIDS	scalar

•
•
•

Repeat NUMNP times

NUMNP = number of nodal points

Description	Variable	Dimension
Equation number associated with active degrees of freedom	ID	NDOF*NUMNP NDOF = maximum nodal active degrees of freedom NUMNP = number of nodal points

•
•
•

Repeat NUMNP times

NUMNP = *number of nodal points*

For truss element groups:

Description	Variable	Dimension
TRUSS element number	M	scalar
Number of nodes to describe this element	IELE	scalar
Flag for printing and saving on porthole the axial stress, strain and force in the element	IS	scalar
Material property set number	MTYP	scalar
Node generation increment used to compute node numbers for missing elements	KG	scalar
Initial axial strain in the element	EPS	scalar
Time of element birth or death	ETIME	scalar
Flag for printing global coordinates of integration points	INTLOC	scalar
Global node numbers		NODE4

⋮

Repeat NPAR(2) times

NPAR(2) = number of truss elements in this group

For 2-D elements group:

Description	Variable	Dimension
2-D SOLID element number	M	scalar
Number of nodes to describe this element	IEL	scalar
Number of the stress table to be used for stress calculations	IPS	scalar
Material property set number assigned to this element	MTYP	scalar
Node generation parameter used to compute node numbers for missing elements	KG	scalar
Material angle β, in degrees, to be used in connection with material model "2" (linear orthotropic)	BET	scalar
Element thickness	THIC	scalar
Time of element birth or death	ETIME	scalar
Flag for printing global coordinates of integration points	INTLOC	scalar
Global node numbers		NODE8

•
•
•

Repeat NPAR(2) times

NPAR(2) = number of 2-D SOLID elements in this group

For 3/D SOLID elements group:

Description	Variable	Dimension
3/D SOLID element number	M	scalar
Number of nodes to be used in describing the element's displacement field	IELD	scalar
Number of nodes to be used in the description of the element's geometry	IELX	scalar
Number of the stress output location table to be used for this element (if a linear material model is used) or flag to output stress at element integration points	IPS	scalar
Material property set number assigned to this element	MTYP	scalar
Material axes orientation set for this element	MAXES	scalar
Flag indicating that the stiffness and mass matrices for this element are the same as those for the preceding elements	IST	scalar
Node number increment for element data generation	KG	scalar
Time of element birth or death	ETIME	scalar
Flag for printing global coordinates of integration points	INTLOC	scalar

Description	Variable	Dimension
Global node numbers		NODE8

⋮

Repeat NPAR(2) times

NPAR(2) = number of 3-D SOLID elements in this group

For beam element groups:

Description	Variable	Dimension
BEAM element number	M	scalar
Assemblage node number at one end (nod 1)	II	scalar
Assemblage node number at other end (node 2)	JJ	scalar
Auxiliary node in r-s local plane	KK	scalar
Material property set number	MTYP	scalar
Number of the stress table to be used for stress output	IPs	scalar
Node generation increment used to compute node numbers for missing elements	KG	scalar
Time of element birth or death	ETIME	scalar
Number of end release table	IELREL	scalar
Flag for printing global coordinates of integration points	INTLOC	scalar

•
•
•

Repeat NPAR(2) times

NPAR(2) = number of beam elements in this group

For isoparameteric beam element groups:

Description	Variable	Dimension
ISO/BEAM element number	M	scalar
Number of nodes to describe this element	IELD	scalar
Flag for stress output	IPS	scalar
Material property set number	MTYP	scalar
Node generation parameter	KG	scalar
Time of element birth or death	ETIME	scalar
Flag for printing global coordinates of integration points	INTLOC	scalar
Global node numbers		NODE4

⋮

Repeat NPAR(2) times

NPAR(2) = number of isoparametric beam elements in this group

For plate/shell element groups:

Description	Variable	Dimension
PLATE/SHELL element number	M	scalar
Number of the stress-resultant table to be used for stress-resultant calculations	IPS	scalar
Material property set number assigned to this element	MTYP	scalar
Node generation parameter used to compute node numbers for missing elements (given on first card of a sequence)	KG	scalar
Material angle β, in degrees to be used in connection with material model "2"	BET	scalar
Element thickness	THIC	scalar
Time of element birth or death	ETIME	scalar
Flag for printing global coordinates of integration points	INTLOC	scalar
Global node numbers		NODE3

•
•
•

Repeat NPAR(2) times

NPAR(2) = number of plate/shell elements in this group

For shell element groups:

Description	Variable	Dimension
SHELL element number	M	scalar
Number of nodes to be used in describing the element's displacement field	IELD	scalar
Number of the stress output location table to be used for this element (if a liner material model is used) or flag to output stresses at element integration points	IPS	scalar
Number of the Shell Thickness Table, to be used for mid-surface nodes	NTH	scalar
Material property set number assigned to this element	MTYP	scalar
Flag indicating that the stiffness and mass matrice for this element are the same as those for the preceding element	IST	scalar
Node number increment for element	KG	scalar
Time of element birth or death	ETIME	scalar
Flag for printing global coordinates of integration points	INTLOC	scalar
Global node numbers		NODE32

•
•
•

Repeat NPAR(2) times

NPAR(2) = number of shell elements in this group

For 2-D fluid element groups:

Description	Variable	Dimension
2/D FLUID element number	M	scalar
Number of nodes to describe this element	IEL	scalar
Flag to output pressures	IPS	scalar
Material property set number assigned to this element	MTYP	scalar
Node generation parameter used to compute node numbers for missing elements	KG	scalar
Time of element birth or death	ETIME	scalar
Flag for printing global coordinates of integration points	INTLOC	scalar
Global node numbers		NODE8

•
•
•

Repeat NPAR(2) times

NPAR(2) = number of 2-D fluid elements in this group

For 3-D fluid element groups:

Description	Variable	Dimension
3/D FLUID element number	M	scalar
Number of nodes to be used in describing the element's displacement field	IELD	scalar
Number of nodes to be used in the description of the element's geometry	IELX	scalar
Flag to output pressures	IPS	scalar
Material property set number assigned to this element	MTYP	scalar
Flag indicating that the stiffness and mass matrices for this element are the same as those for the preceding element	IST	scalar
Node number increment for element data generation	KG	scalar
Time of element birth or death	ETIME	scalar
Flag for printing global coordinates of integration points	INTLOC	scalar
Global node numbers	NODE	21

•
•
•

Repeat NPAR(2) times

NPAR(2) = number of 3-D fluid elements in this group

3.5.25 Tape 60

Specifications:

- Sequential access file
- The porthole (graphics) file for saving nodal/element responses (if requested)

Comment:

The porthole (graphics file) creation is employed to store data for use with ADINA-PLOT. This program can be directly used to access the stored input data and ADINA output for graphical display and selective listing operations. Current logical units in ADINA are:

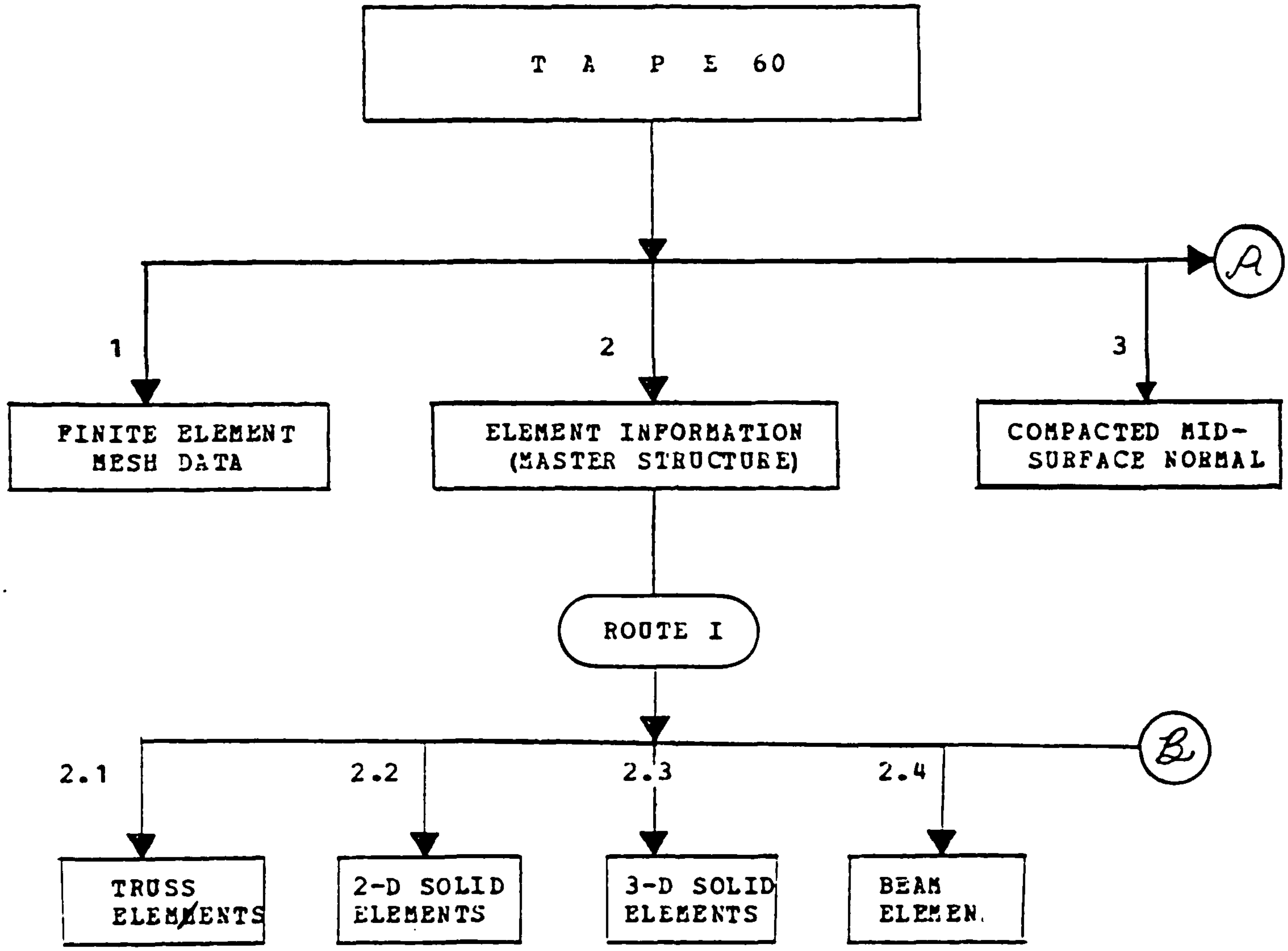
LUNODE = for the tape on which node associated data and/or results are to be written

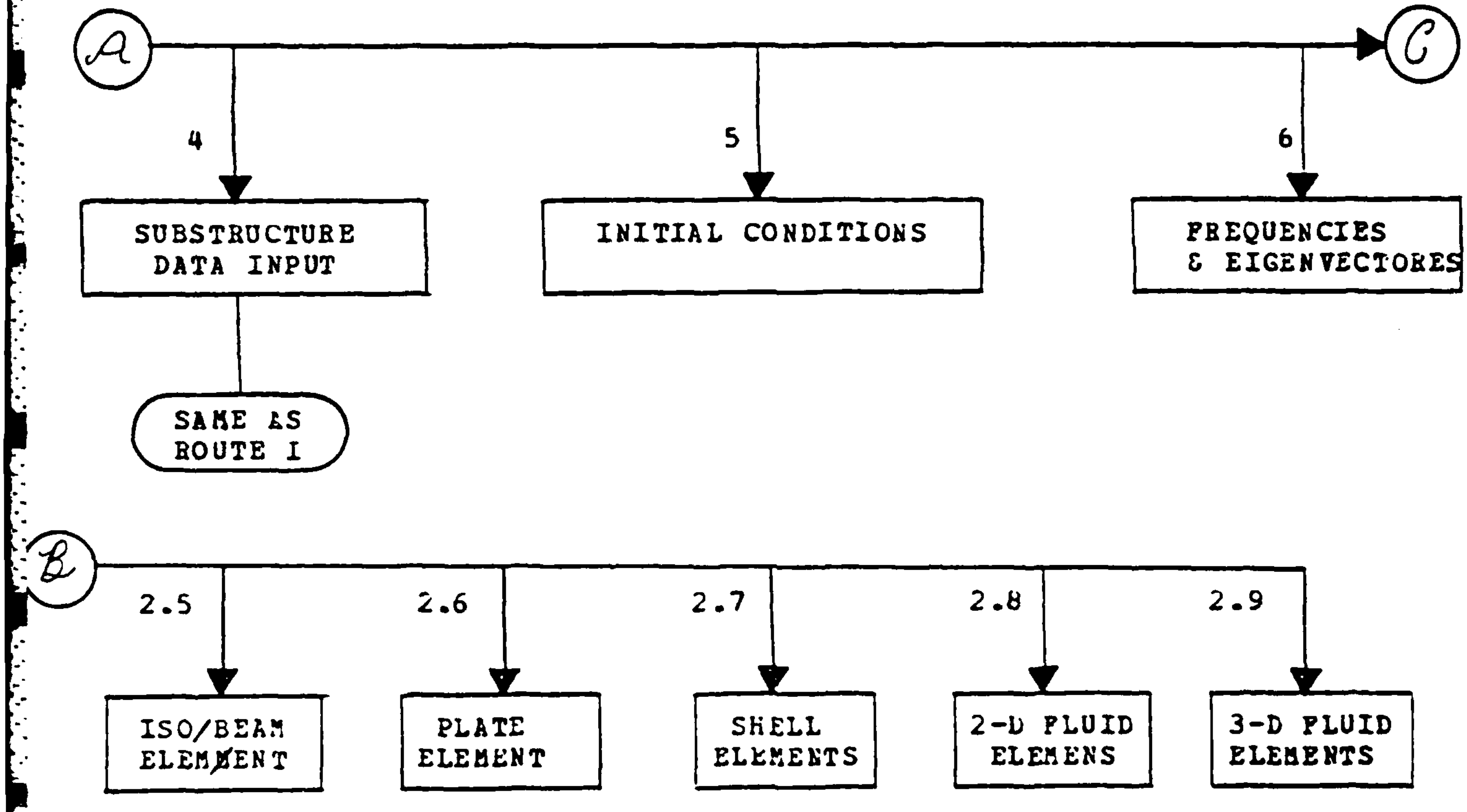
LU1 = for the tape on which TRUSS, 2-NODE BEAM, ISO/BEAM element data and/or results are to be written

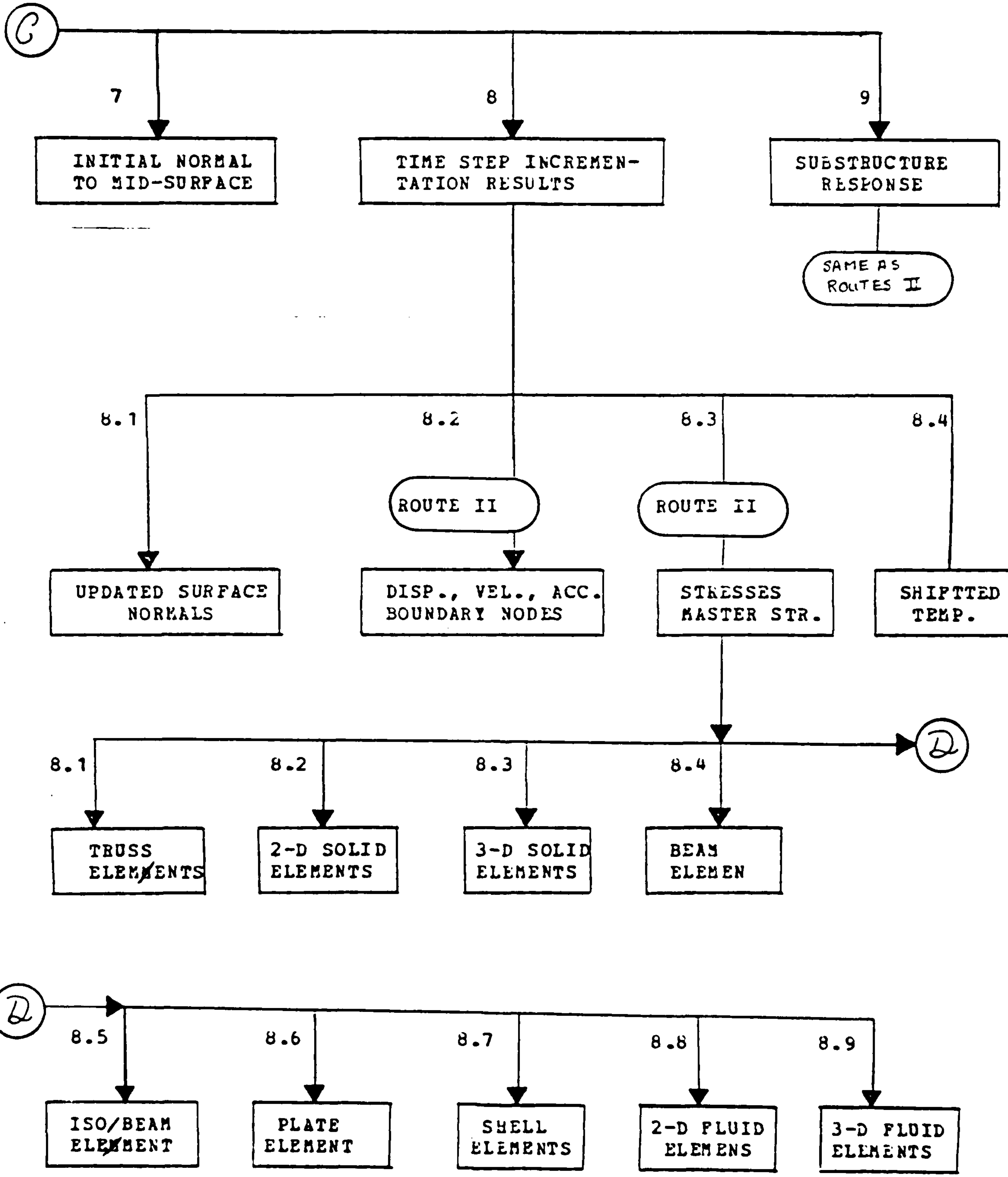
LU2 = for the tape on which 2/D SOLID, 2/D FLUID element data and/or results are to be written

LU3 = for the tape on which 3/D SOLID, PLATE, SHELL and 3/D FLUID element data and/or results are to be written

Since our target is design of a database for design optimization problems, we impose same logical units to store nodal and element respones. Suppose we assign LUNODE = LU1 = LU2 = LU3 = 60. Then, following information is stored sequentially on Tape 60. Note that first value of each record on Tape 60 is a character*8 variable which defines the stored information following the record. For example, a variable like 'MATERAL6' specifies material information of plate element stored in that record. This tape is very big, we only describe a few of the data items on the tape in attached flow diagrams.


T A P E 60
A
1
2
3
FINITE ELEMENT MESH DATA
ELEMENT INFORMATION (MASTER STRUCTURE)
COMPACTED MID-SURFACE NORMAL
ROUTE I
B
2.1
2.2
2.3
2.4
TRUSS ELEMENTS
2-D SOLID ELEMENTS
3-D SOLID ELEMENTS
BEAM ELEMEN


A
C
4
5
6
SUBSTRUCTURE DATA INPUT
INITIAL CONDITIONS
FREQUENCIES & EIGENVECTORES
SAME AS ROUTE I
B
2.5
2.6
2.7
2.8
2.9
ISO/BEAM ELEM~~M~~ENT
PLATE ELEMENT
SHELL ELEMENTS
2-D FLUID ELEMENS
3-D FLUID ELEMENTS


C
7
8
9
INITIAL NORMAL TO MID-SURFACE
TIME STEP INCREMENTATION RESULTS
SUBSTRUCTURE RESPONSE
SAME AS ROUTES II
8.1
8.2
8.3
8.4
ROUTE II
ROUTE II
UPDATED SURFACE NORMALS
DISP., VEL., ACC. BOUNDARY NODES
STRESSES MASTER STR.
SHIPTTED TEMP.
D
8.1
8.2
8.3
8.4
TRUSS ELEMENTS
2-D SOLID ELEMENTS
3-D SOLID ELEMENTS
BEAM ELEMEN
D
8.5
8.6
8.7
8.8
8.9
ISO/BEAM ELEMENT
PLATE ELEMENT
SHELL ELEMENTS
2-D FLUID ELEMENS
3-D FLUID ELEMENTS

3.6 DISCUSSION

In this chapter, ADINA's database is described. Section 3.5 explains each tape. Although the section is not comprehensive, it contains the basic structure of ADINA database. Tapes 50, 59, and 60 are not database files. Tape 59 is a preprocesser input file and 60 is the porthole (graphics) file. Nodal/element responses are available on Tape 60. This can be used as a basic tape for most of the required information in design sensitivity analysis and optimization. Further information about tape allocations is given in a report by Haririan and Arora (1984).

4. ANALYSIS OF GIFTS' DATABASE

4.1 INTRODUCTION

GIFTS is a pre- and post-processing and structural analysis package based on finite element technique (Kamel and McCabe, 1979, 1981). It produces and maintains data sets containing all information of finite element analysis. Data sets are generated on the user disk in binary format.

The purpose of this chapter is to analyze the GIFTS database which may also be used for structural optimizaιion. To access data sets, it is necessary to have a proper knowledge of the data structure used in GIFTS. Program structure is presented in Section 4.2. Brief description of each module is also given there. Section 4.3 shows the data structure of the random access files generated by GIFTS which may be permanent or temporary. Data sets generated by GIFTS are listed in Section 4.4. Section 4.5 shows the usage of data sets in each module. Detailed data set contents are described in Section 4.6. It is noted that the term 'data set' is used in place of 'data file' since each data file of GIFTS contains only one data set.

4.2 STRUCTURE OF PROGRAM GIFTS

GIFTS is a group of fully compatible modules, constituting a program library. Each module is used for specific function such as stiffness matrix computation, load and boundary condition generation, etc. To perform complete analysis using GIFTS, a number of modules needs to be executed. There are procedures for static analysis, substructuring, and dynamic analysis.

GIFTS contains both batch and interactive modules. A batch module should be run in remote batch mode. It deposits results in the database using a standard format, so that they can be accessed by the user. The only input for this case is the job name.
An interactive module follows a reasonable sequence of instructions given from a graphics terminal. It usually has plotting capabilities. Figures 4.1 and 4.2 show the structure of batch and iteractive modules of GIFTS, respectively.

Some GIFTS modules are used in a number of solution procedures. They are described below.

4.2.1 Model Generation and Editing

BULKM is an automated 3-dimensional plate and shell model generator. It is suitable for large continuous structures that can be easily modeled by repetitive generation of points and elements.

BULKS is a 3-dimensional solid model generator. One may ask for the display of the edges, and may add and display selected points and element slices.

EDITM Updates and corrects BULKM models. It can also be used to generate simple models and the ones too complex for BULKM module.

DEFCS accepts information regarding external and dependent boundary nodes in a constrained substructure.

EDITS is a 3-dimensional solid mesh editor. It is not available in current version at the University of Iowa.

4.2.2 Load and Boundary Condition Generation and Editing

BULKF is intended to allow only those freedoms that a model can support.

BULKLB is a bulk load and boundary condition generator which is applied to models generated with BULKM. These include distributed line and surface loads and masses, prescribed displacements along lines and surfaces, and inertial loads. Temperatures may be also specified.

EDITLB is a display and edit module intended to provide local modification capability for loads and boundary conditions applied by BULKLB module. It may also be used to generate simple loading on models, or loading not generated with BULKLB. Temperatures may also be specified for elements. After the DEFL module has been run, thermal and combined loads may be examined.

LOADS is a load and boundary condition generator for solid models. Loads may be distributed on lines or surfaces. Loads and boundary conditions may be displayed on point slices.

4.2.3 General Purpose Computational and Result Display

OPTIM is a bandwidth optimization module. It may be called several times, until the best node numbering is achieved.

STIFF computes element stiffness matrices and assembles them into the system stiffness matrix.

DECOM introduces kinematic boundary conditions, and decomposes the stiffness matrix using Cholesky's method.

DEFL computes the deflections using the current loading conditions and the decomposed stiffness matrix. If temperatures are present, thermal forces will be calculated and added to the current applied loads before computation.

STRESS computes element stresses based on current deflections.

RESULT displays deflections and stresses.

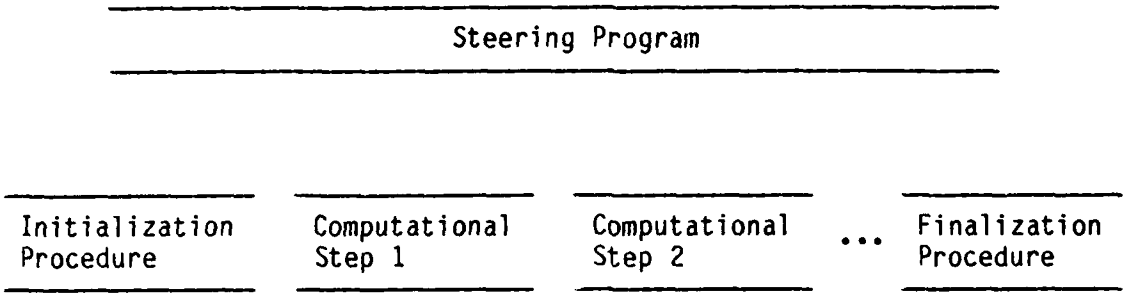


Figure 4.1 Structure of GIFTS Batch Module

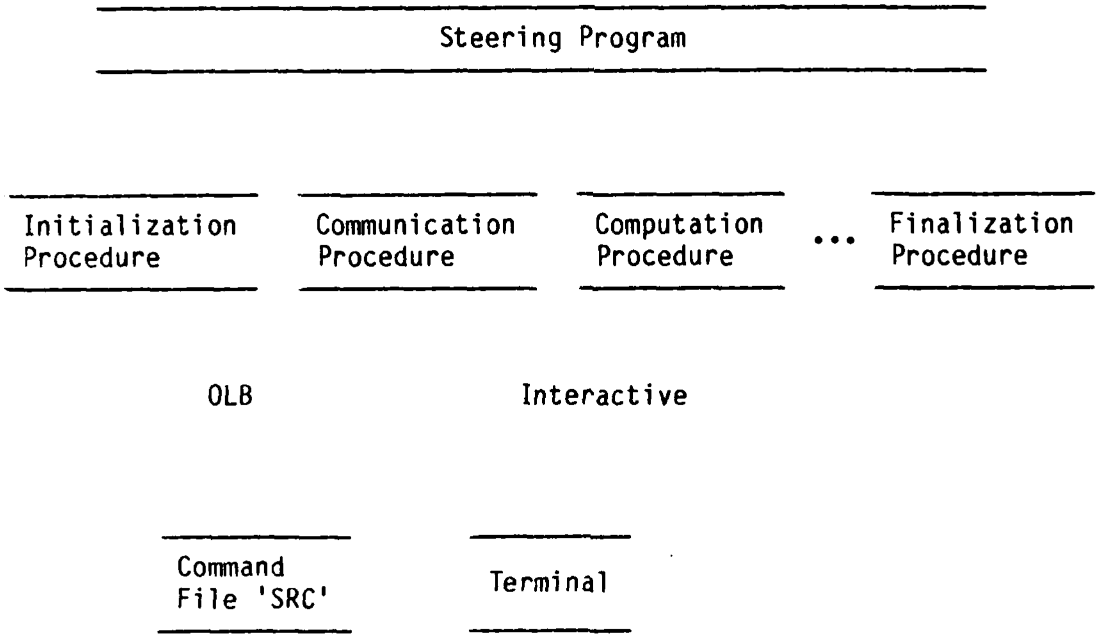


Figure 4.2 Structure of GIFTS Interactive Module

4.2.4 **Free Vibration Analysis** (Subspace Iteration Method)

AUTOL is for automatic generation of starting iteration vectors for the subspace iteration method.

SUBS performs a single subspace iteration to determine the natural modes of vibration. It must be repeated as many times as necessary to obtain convergence to desired accuracy.

The program execution sequence is as follows:

BULKM EDITM	model generation
BULKF	determination of basic freedom pattern
OPTIM	bandwidth optimization
BULKLB EDITLB	definition of number of modes and kinematic boundary conditions
AUTOL	automatic load generation
STIFF	computation of stiffness matrix
DECOM	matrix decomposition
SUBS	subspace iteration routine
RESULT	display of current mode shapes and stresses.

4.2.5 **Transient Response Analysis** (Houbolt Method)

TRAN1 is used to specify the time stepsize to be used in the integration process. It computes the initial acceleration and the effective stiffness matrix.

TRAN2 computes the displacement for time t = Δt by inverting the decomposed effective stiffness matrix. It computes the second effective stiffness matrix for all subsequent time steps.

TRANS computes the displacement for all time steps after t = Δt. It maintains and plots history of the displacements (upto four different freedoms).

The program execution sequence is as follows:

BULKM EDITM	model generation
BULKF BULKLB EDITLB	generation of load functions at different time values mass and damping coefficient generation

OPTIM bandwidth optimization

STIFF stiffness matrix generation

TRAN1
DECOM definition of time stepsize, and initiation of integration
TRAN2 procedure
DECOM

TRANS user controlled time integration

STRESS stresses of time steps set up by TRANS

RESULT display of time steps set up by TRANS.

4.2.6 Constrained Substructure Analysis (COSUB)

REDCS computes condensed stiffness and load matrices. It prints residual forces to check accuracy of COSUB generation.

LOCAL is used to extract the deflections of each external node of the desired COSUB from the master analysis model. It uses them to compute displacements of all the dependent boundary points, with the partial displacement matrix due to internal loading (computed by REDCS), and all of the internal nodes of the COSUB model.

The program execution sequence is as follows:

Generation of COSUB Model

BULKM
EDITM
BULKF
BULKLB
EDITLB
OPTIM
DEFCS
STIFF
DECOM
REDCS

Generation of Main Analysis Model

BULKM
EDITM
BULKF
BULKLB
EDITLB
OPTIM
STIFF
DECOM
DEFL
STRESS

Local Analysis of COSUB

LOCAL
STRESS

4.3 DATABASE STRUCTURE

GIFTS has a well defined database structure. A complete description of the database is important to a user. Following terminologies are defined to describe the database of GIFTS:

1. Logical Records (LRS)

A logical record is the smallest unique collection of data contained in a data set. For example, all data pertaining to one node or one element is called one logical record. This data is passed to and from the GIFTS system's I/O subroutines via labelled common blocks as individual logical records.

2. Physical Records (IPRS)

A physical record is a collection of data read from or written to a data set with a single I/O operation. It consists of any number of logical records.

3. Blocking Factor (IBF)

Number of logical records in a physical record is defined as the blocking factor (i.e., IPRS = IBF*LRS).

4. Logical Record Group (NLRG)

Some data sets contain a group of logical records, all of which share some common attributes in those data sets (e.g., same loading case number). Figure 4.3 shows structure of random and sequential access type databases.

4.4 DATA SETS IN GIFTS

Data sets are generated by the system automatically during the execution of any solution procedure. The data sets are either sequential or random access, and permanent or temporary. Permanent data sets exist in user's subdirectory with a name of D-G.jobname. Jobname is to be specified by the user. Temporary data sets exist only during the execution of the program, and are deleted upon successful termination of the program. Table 4.1 shows a list of data sets used in GIFTS system.

4.5 UTILIZATION OF DATA SETS

Table 4.2 shows use of data sets in various modules. A row in the table indicates the total number of data sets utilized by each module. The contents of each data set may be changed or unchanged during the execution of GIFTS. Execution procedure can be classified into three stages; pre-processing, analysis, and post-processing. It is recommended that the data sets should not be directly accessed during the analysis stage.

GIFTS Prime version utilizes up to 10 random access and 3 sequential access data sets, simultaneously. In case more than 10 random data sets are used, the module automatically closes a file before another is opened. For random-access data set utilization within a module, the labelled common block containing the buffer should be core-resident from the time the data set is opened to the time it is closed.

During execution of GIFTS system, only 13 logical device numbers are used, and these are assigned by special GIFTS routines during execution of a module. Table 4.3 provides these numbers used in GIFTS 5.03 Prime version. It contains subroutine names which assign these numbers, so that they may be altered for other systems.

4.6 DETAILED DESCRIPTION OF DATA SETS

This section provides the detailed description of logical second contents for random access data sets, except the data sets 'PAR' and 'FIL'. For these data sets, the description is for each physical record. The contents of sequential access data sets are also described.

In GIFTS5 system, the data sets can be classified into 7 groups according to their utilization:

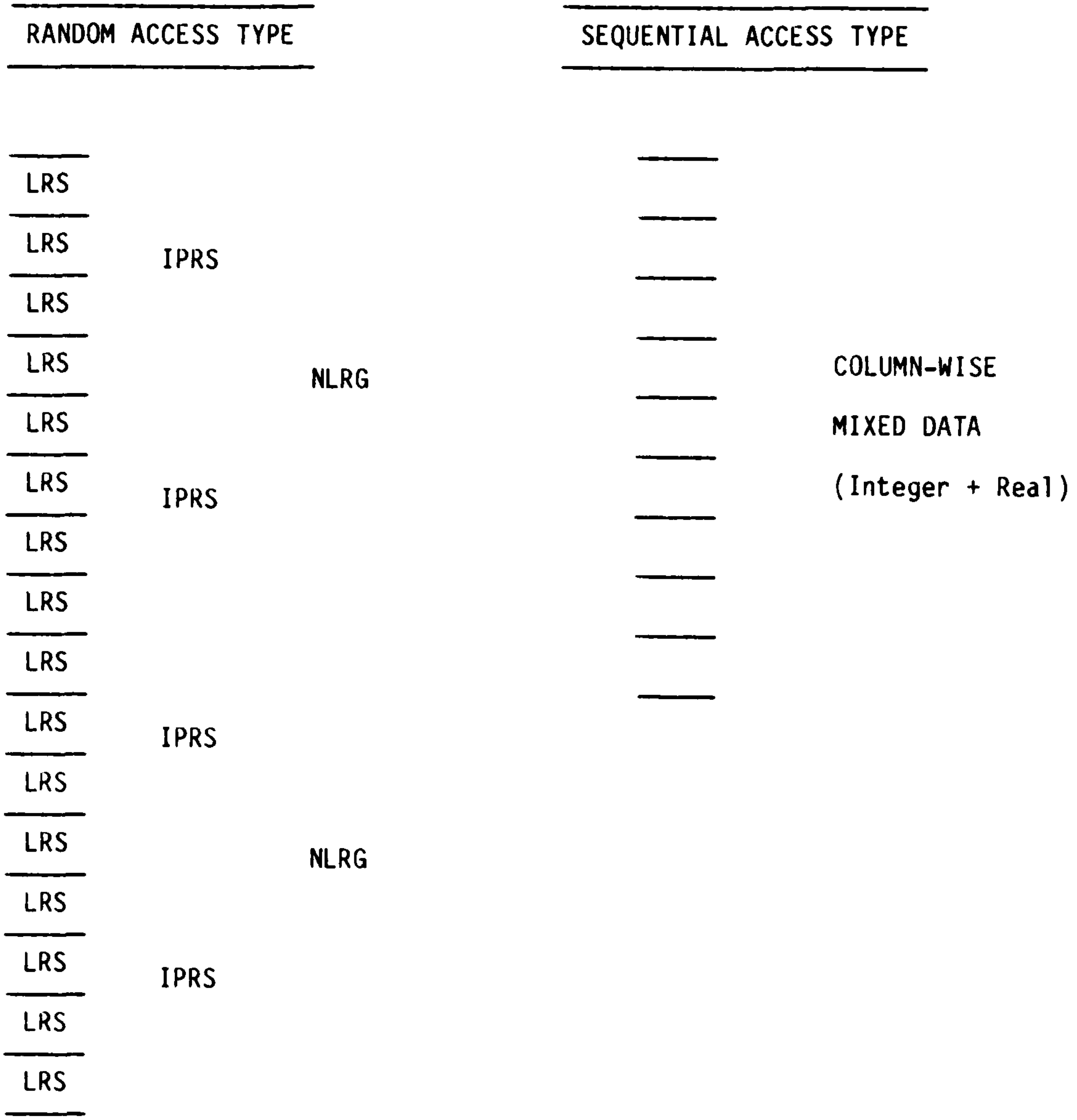
1. System and Data Set Management Group
2. Model Generation Group
3. Static Analysis Group
4. Dynamic Analysis Group
5. Substructural Analysis Group
6. Axisymmetric Analysis Group
7. Temporary Group

These data sets are generated in such a manner that the extra data sets are added to the basic groups 1, 2 and 3. For example, 8 data sets (LDT, DNT, SAV, HST, DNH, UGC, DYN, GCS) are generated during the execution of dynamic analysis (modal analysis or transient response analysis).

All random access data sets have default sizes and are varied according to the problem size. Specifications of these data sets are stored and updated via the data set 'FIL'. The following is the detailed descriptions of each data set.

4.6.1 System and Data Set Management Group

The data sets 'PAR' AND 'FIL' are classified as a system and data set management group. These data sets are utilized in all modules.



NOTES: IPRS = Physical Records, LRS = Logical Records
NLRG = Logical Record Group.

Figure 4.3 Database Structure of GIFTS

Table 4.1 List of Data Sets in GIFTS

DATA SET	IPRS		CONTENTS
NAME	LRS	IBF	
PAR	25	1	System and Problem Control Parameters
FIL	7	1	File Specification Management
LIN	49	10	Line Generation Logic
GRD	63	5	Grid Generation Logic
PTS	44	10	Nodal Point Generation Logic
ELT	45	10	Element Generation Logic
MAT	27	5	Material Definition Data
THS	36	5	Thickness/Area Information
SUR	65	5	Surface Generation Logic
SLD	147	1	Solid Element Generation Logic
SLI	18	10	Slice Element Generation Logic
SDY	42	5	Stiffness Matrix Directory
STF	652	1	Stiffness Matrix
SD2	21	5	Stiffness Matrix Directory (Axi-symm.)
STC	652	1	Stiffness Matrix (Axi-symm.)
LDC	16	10	Nodal Point Loads
LDI	364	1	Internal Loads
LDS	16	10	Nodal Point Loads
LDT	146	1	Temporary Load, Mass and Damping coeff.
ELD	70	5	Element Loads
PLD	22	10	Point Loads
TLD	168	5	Thermal Loads
STR	16	10	Element Stresses
TEM	652	1	Element Temperature for COSUB
TMP	56	5	Element Temperature
DNH	12	10	Displacement History
DNI	364	1	Internal Deflections
DNS	16	10	Nodal Point Deflections
DNT	146	1	Previous Transient Response Data
ELS	24	10	Principal Stresses (T)
RES	168	5	Residual Stresses
UGC	364	1	Unit Generalized Displacement

Table 4.1 (Continued)

DATA SET	IPRS		CONTENTS
NAME	LRS	IBF	
CFR	SEQUENTIAL		Stress contour values
HST	SEQUENTIAL		Histogram of Selected D.O.F.
DYN	SEQUENTIAL		Condensed Matrices for Modal Analysis
SAV	SFQUENTIAL		Stiffness Save File
DGT	SEQUENTIAL		Digitizer Information for Plotting
CPF	SEQUENTIAL		Digitizer Information for COSUB Plot
INT	5	10	Boundary Interpolation Directory for COSUB
TDE	652	1	Transformation Matrices for COSUB
TIE	652	1	Transformation Matrices for COSUB
KEE	652	1	Condensed Stiffness Matrix for COSUB
MEE	652	1	Condensed Mass Matrix for COSUB
CEE	652	1	Condensed Damping Matrix for COSUB
CLD	364	1	Condensed Load Vector for COSUB
CDN	364	1	Internal Displacements for COSUB
OP0	2	40	Nodal Point Directory (T)
OP1	4	40	Nodal D.O.F. and Information Directory (T)
OP2	2	40	Element Information Directory (T)
OP3	1	40	List of the corner nodes for each element (T)
PTX	44	10	Temporary Nodal Points (T)
TMX	56	5	Temporary Element Temperature (T)
LDX	16	10	Temporary Nodal Point Loads (T)
SLX	18	10	Temporary Solid Element (T)

NOTES (T): Temporary Data Sets
COSUB: Constrained Substructuring.

REMARKS

1. The data sets listed above refer to GIFTS5 Prime Version at CAELAB, University of Iowa.

2. The data sets generated in other directories are not listed here. These are as follows:
   -SRC : User Command File generated in user's home directory in case of OLB (On-Line-Batch) mode.
   -EST,$EST: System Files for estimating the CPU times of subsequent modules.
   -INF : System Information File for the user in interactive mode.

Table 4.2 Data Set Utilization in GIFTS5

1.

DATA SET MODULE	PAR	FIL	LIN	GRD	SLD	SLI	PTS	ELT	MAT	THS	SUR	ELD	TLD	LDS
BULKM	x	x	x	x			x	x	x	x	x			
EDITM	x	x	x	x			x	x	x	x	x			x
BULKF	x	x					x	x		x				
OPTIM	x	x					x	x		x				
BULKLB	x	x					x	x	x	x		x		x
EDITLB	x	x					x	x		x		x		x
STIFF	x	x					x	x	x	x				
DECOM	x	x					x							
DEFL	x	x					x	x	x	x			x	x
STRESS	x	x					x	x	x	x		x		
RESULT	x	x					x	x	x	x		x		
SAVEK	x	x												
RESIDU	x	x					x							
BULKS	x	x	x	x	x	x	x	x	x	x	x			
LOADS	x	x	x	x	x	x	x	x	x	x		x		x
AUTOL	x	x					x							x
SUBS	x	x					x							x
TRAN1	x	x					x							x
TRAN2	x	x												
TRANS	x	x					x							x
DEFCS	x	x	x				x	x		x				x
REDCS	x	x					x							x
LOCAL	x	x	x				x	x	x	x				

Table 4.2 (Continued)

2.

DATA SET MODULE	PLD	LDC	LDI	SDY	STF	SD2	STC	STR	TEM	TMP	DNH	DNI	DNS	DNT	LDT
BULKM															
EDITM															
BULKF															
OPTIM															
BULKLB	x									x					
EDITLB										x					
STIFF				x	x										
DECOM				x	x										
DEFL		x	x	x	x			x		x		x	x		
STRESS								x		x			x		
RESULT								x					x		
SAVEK					x										
RESIDU			x												
BULKS															
LOADS										x					
AUTOL															
SUBS			x	x	x							x	x		x
TRAN1			x	x	x										x
TRAN2				x	x									x	x
TRANS			x	x	x						x		x	x	x
DEFCS															
REDCS			x	x	x				x						
LOCAL												x	x		

Table 4.2 (Continued)

3.

DATA SET MODULE	ELS	RES	UGC	INT	TDE	TIE	KEE	MEE	CEE	CLD	CDN	HST	DYN	SAV
BULKM														
EDITM														
BULKF														
OPTIM														
BULKLB								x	x					
EDITLB		x								x				
STIFF							x							
DECOM														
DEFL														
STRESS	x													
RESULT	x													
SAVEK														x
RESIDU		x												
BULKS														
LOADS														
AUTOL														
SUBS			x										x	
TRAN1														x
TRAN2														x
TRANS												x		
DEFCS				x										
REDCS				x	x	x	x	x	x	x	x			
LOCAL					x	x					x			

Table 4.2 (Continued)

4.

DATA SET MODULE	CFR	DGT	CPF	OP0	OP1	OP2	OP3	PTX	TMX	LDX	SLX
BULKM		x						x			
EDITM		x						x		x	
BULKF		x									
OPTIM		x		x	x	x	x				
BULKLB		x							x	x	
EDITLB		x							x	x	
STIFF		x									
DECOM		x									
DEFL		x									
STRESS		x									
RESULT	x	x	x								
SAVEK		x									
RESIDU		x									
BULKS		x									x
LOADS		x								x	
AUTOL		x									
SUBS		x									
TRAN1											
TRAN2											
TRANS											
DEFCS			x								
REDCS			x								
LOCAL			x								

Table 4.3 Usage of Logical Device Numbers in GIFTS5*

Device Number	Device	Subroutine Involved
1	Terminal Input	INITIO
1	Terminal Output	INITIO
0	Line Printer	OPENLP, CLOSLP
1 2 3 4 5 7 8 9 10 11	Random DiskI/O	SLTASN (for assigning the logical device no.) FRESLT (for freeing the logical device no.)
16 17 18	Sequential Disk I/O	SLTASN FRESLT

* Prime Version at the Computer Aided Engineering Laboratory, University of Iowa

PAR

Type	;	Random Access
Status	;	Permanent, INTS

Data Size Parameters	;	IPRS = 25 (words)
		IBF = 1
		LRS = 25
		IPRN = 10 (no. of physical records)

Data Set Description. This data set contains general system information and problem control parameters. Each physical record has a different type of information. The number of physical records is fixed to 10.

Logical Record Contents. The following is the 10 logical record content.

1. Hardware Values: 13 integer

Location	Variable	Description
1	NWF1	Storage Units (bytes/words) per single precision real variable
2	NWF2	Storage Units per double precision real variable
3	NWI	Storage Units per integer (INTS)
4	NRUXM	Number of Raster Units in x-direction on main viewing area
5	NRUYM	Number of Raster Units in y-direction on main viewing area
6	NRUXO	Number of Raster Units in x-direction on offset viewing area
7	NRUYO	Number of Raster Units in y-direction on offset viewing area.
8	NRUXSC	Small character size in Raster Units
9	NRUYSC	
10	NRYXLC	Large character size in Raster Units
11	NRUYLC	
12	NRUXDT	Number of Raster Units in x-direction of Digitizing Tablet
13	NRUYDT	Number of Raster Units in y-direction of Digitizing Tablet
14-25	-	Unused

2. GIFTS Limitations: 5 integer

Location	Variable	Description
1	NCPPEM	Max. number of corner points per element (27 in current version)
2	NFGM	Max. number of freedoms per group (18 in current version)
3	NSRM	Max. number of strings in row of stiffness sub-matrix BK (9 in current version)
4	NLCSM	Max. number of loading cases that can be simultaneously handled in solution routine (10 in current version)
5	NSTRM	Max. number of stresses per stress point including failure criterion (8 in current version)
6-25	-	Unused

3. Problem Size/Counters: 23 integer

Location	Variable	Description
1	NGPT	Total Number of Points (No. of logical records in data set 'PTS')
2	NGPA	Total number of active points (Acutal and Lagrange points)
3	NELTS	Total number of elements
4	NKPT	Total number of key points
5	NL	Total number of lines
6	NG	Total number of surface grids
7	NS	Total number of solid grids
8	NMATT	Total number of materials
9	NTHS	Total number of thickness groups
10	NDFPM	Max. number of degrees of freedom per node
11	NBCPT	Total number of boundary condition points
12	NUGRP	Total number of unknown groups in solution
13	NLCT	Total number of loading cases (load groups)
14	NLCA	Total number of active loading cases
15	NDST	Total Number of deflection per stress groups (equal to NLCA for static analyses; defined by user with 'SETUP' commands for Transient Response Analyses)
16	NGCGT	Total number of generalized coord. groups (or modes of vibration)
17	NGCGA	Total number of active generalized coord. groups (used in Transient Response by modes)
18	NSTRR	Total Number of records in stress file
19	NFILL	Number of files used (excluding 'PAR' and 'FIL' files)
20	IFREE	Unused
21	NSTEP	Number of transient response steps saved
22	NFIB	Block number of first freedom to be condensed
23	NUNKT	Total number of unknowns
24-25	IFREE(2)	Unused.

4. Problem Status: 16 integer

Location	Variable	Description
1	ISTM	Model Generation Status 0 - Model Not Generated 1 - Model Generated the following values are added to form the complete switch value 2 - Thickness Group Modified 4 - Material Added 8 - Thickness Group Modified 16 - Material Modified 32 - Nodes Created, Deleted or Redefined (Moved) 64 - Elements Added, Deleted or Modified 128 - Material Nonlinearily Switches changed 256 - Geometric Nonlinearity Switches changed
2	ISTPM	Point Mass Generation Switch 0 - Point Masses Not Generated 1 - Point Masses Generated 2 - Point Masses Modified
3	ISTBWO	Bandwidth Optimization Switch 0 - Bandwidth Not Optimized 1 - Bandwidth Optimized
4	ISTST	Stiffness Formation Switch 0 - Nonexistant 1 - Stiffness Directory Present 2 - Stiffness Directory and Matrix Present (Components present if Axi-symm.)
5	ISTKS	Stiffness Save Switch 0 - Not Saved 1 - Saved in 'SAV' data set
6	ISTLD	Load Generation Status 0 - Not Generated 1 - Generated 2 - Modified

4. Problem Status: 16 integer (Continued)

Location	Variable	Description
7	ISTBC	Boundary Condition Status
		0 - Not Imposed
		1 - Imposed
		2 - Modified
8	ISTDEC	Stiffness Decomposition Status
		0 - Not Decomposed
		1 - Decomposed
9	ISTDN	Deflection Generation Status
		0 - Not Computed
		1 - Computed
10	ISTCD	COSUB Reduction Status
		0 - Not Reduced
		1 - Stiffness Matrix Reduced
		2 - Load Matrix Reduced
		3 - Stiffness, Load Matrices Reduced
		4 - Mass, Damping Matrices Reduced
		5 - Stiffness, Mass, Damping Matrices Reduced
		6 - Stiffness, Mass, Damping and Load Matrices Reduced
11	ISTTRF	Transient Response Status
		0 - Unstarted
		1 - Module 'TRAN1' Ran/executed
		2 - Module 'TRAN2' Ran/executed
		3 - Module 'TRANS' Ran/executed
12	ISTTRM	Transient Response Status (Modal Analysis)
		0 - Unstarted
		>0 - Undefined
13	ISTES	Element Stress Switch
		0 - Not Computed
		1 - Computed
14	ISTESN	Element Strain Switch
		=0 - Not Present
		=1 - Present

4. Problem Status: 16 integer (Continued)

Location	Variable	Description
15	ISTPF	Auxiliary Plot File Status =0 - Not Present =1 - Present
16	ISTUNS	Variable to Flag GIFTS Solution Suitability =0 - Model can be solved by GIFTS >0 - Model cannot be solve by GIFTS The following numbers are added to obtain the final flag 1 - Nonsupported Material Used 2 - Nonsupported Element Used 4 - Prescribed Displacements Used 8 - Nonlinearities Expected
17-25	IFRE(P)	Unused

5. Problem Mode Switches: 11 integer

Location	Variable	Description
1	ISWFP	Floating Precision Switch
		=1 - Single Precision
		=2 - Double Precision
2	ISWPC	Problem Class Switch
		=1 - 2-D Field
		=2 - 2-D Elastic/Plastic
		(Plane Stress/Plane Strain)
		=3 - 3-D Field
		=4 - 3-D Elastic/Plastic (Shell/Solid)
		=5 - Axisymmetric Field
		=6 - Axisymmetric Elastic/Plastic
		=7 - Axisymmetric Field (General Loading)
		=8 - Axisymmetric Elastic/Plastic (General Loading)
3	IFREE	Unused
4	ISWSY	Symmetry Switch
5	ISWTH	Thermal Stress Switch
6	ISWEM	Eigenmode Switch
7	ISWCS	Constrained Substructure Switch
8	ISWINC	Incremental Mode Switch
9	ISWTR	Transient Response Switch
		0 - None
		1 - Full D.O.F. Analysis
		2 - Modal Analysis
10	ISWMNL	Material Nonlinearity Switch
		0 - Linear
		1 - Nonlinear
11	ISWGNL	Geometric Nonlinearity Switch
		0 - Linear
		1 - Nonlinear
12-25	IFREE(14)	Unused

6. Display Box Parameters: 10 floating point

Location	Variable	Description
1-2	XMINBX	Virtual Coordinate Limits for Plot
3-4	XMAXBX	
5-6	YMINBX	
7-8	YMAXBX	
9-10	ZMINBX	
11-12	ZMAXBX	
13-14	XMINSC	Screen Coordinate Limits for Plot
15-16	XMAXSC	
17-18	YMINSC	
19-20	YMAXSC	
21-25	IFREE(5)	

7. Additional Display Parameters: 11 floating point + 2 integer

Location	Variable	Description
1-2	SCLM	Model Scale
3-4	VDIST	Viewing Distance
5-22	TRAN(3,3)	Global-Screen Coordinate Transformation Matrix
23	ISWRNG	Failure Criteria Range Switch =0 - No Range Specified =1 - Ranges Specified
24	ISWCNT	Contour Value Switch
25	IFREE	Unused

8. Misc. Problem Parameters: 9 floating point

Location	Variable	Description
1-2	XMIN	Coordinate Limits of Model
3-4	XMAX	
5-6	YMIN	
7-8	YMAX	
9-10	ZMIN	
11-12	ZMAX	
13-14	DEL	Current Time Step Size (Transient Response)
15-16	TM	Current Time Indicator (Transient Response)
17-18	CHBW	Computational Half-Bandwidth
19-25	IFREE(7)	Unused

9. Misc. Problem Parameters: 7 floating point

Location	Variable	Description	
1-2	UDBVER	Database Version Name (Alphanumeric)	
3-4	ACPTI	Accumulated CPU Time	Interactive Modules
5-6	AIOTI	Accumulated I/O Time	
7-8	AWCTI	Accumulated Wall Clock Time	
9-10	ACPTC	Accumulated CPU Time	Computational Modules
11-12	AIOTC	Accumulated I/O Time	
13-14	AWCTC	Accumulated Wall Clock Time	
15-25	IFREE(11)	Unused	

10. Misc. Problem Parameters: 9 integer

Location	Variable	Description
1	NEP	Number of External Points in Constrained Substructure Model
2	NDP	Number of Dependent Points in Constrained Substructure Model
3	NIP	Number of Internal Points in Constrained Substructure Model
4	NINT	Total Number of Interfaces Defined for Constrained Substructure
5	NIT	Total Number of Time Steps Computed (Transient)
6	NHARM	Highest Axisymmetric/General Harmonic Computed
7	IFREE	Unused
8	NARBG	Current Arbitrary Grid Number
9	NARBS	Current Arbitrary Solid Number
10-25	IFREE(16)	Unused

FIL

Type ; Random Access

Status ; Permanent, INTS

Data Size Parameters ; IPRS = 7 (words)
IBF = 1
LRS = 7

Data Set Description. This data set contains the data size parameters for all the random access data sets generated by GIFTS. The number of physical records is the number of data sets with random access type including 'FIL' itself.

Logical Record Contents (1 floating point + 5 integer)

Location	Variable	Description
1-2	EXT	Data Set Name (Alphanumeric)
3	LRS	Logical Record Size (in words)
4	LRN	Number of Logical Records Defined
5	IBF	Blocking Factor
6	IPRS	Physical Record Size (LRS*IBF)
7	IPRN	Number of Physical Records

4.6.2 Model Generation Group

The following data sets are classified as 'model generation group'. They are generated by the system during the model generation procedures. The data sets named PTS, ELT, SUR, SLI, LIN, THS, MAT, GRD and SLD fall into this group.

PTS

Type	;	Random Access
Status	;	Permanent, INTS

Data Size Parameters	;	IPRS = 440 (words)
		IBF = 10
		LRS = 44

Data Set Description. This data set contains the nodal point generation logic with user node numbers and system node numbers. Each logical record consists of 10 integer and 17 floating point variables. For boundary condition points, the different variables are stored in the corresponding logical records space with a flag number NU = 32767 in the first location of the logical records.

Logical Record Contents (10 integer + 17 floating point)

Data Set: PTS

Location	Variable	Description
1	NU	User Number of System Node 'I' (Negative Number Flags for Deleted/Merged Node)
2	NS	System Node Number for User Node 'I'
3	ISTRKT	Structure Flag (= ITY + 8*N) ITY = 0 - Unassociated Node = 1 - Key Node = 2 - Internal to Boundary Line #N = 3 - Internal to Grid #N = 4 - Internal to Solid #N
4	IPTPLT	Plot Indicator =0 - Don't Plot =1 - Plot
5-6	X	
7-8	Y	Nodal Point Coordinates
9-10	Z	
11-16	SM(3)	Point Masses in Three Directions
17-22	C(3)	Point Damping Coefficients in Three Directions
23-38	WRKPAD(8)	Scratch Space
39	LMN	Inclined Boundary Condition Indicator =0 - No Inclined Boundary Conditions >0 - Inclined Boundary Conditions Exist for this Node. Transformation Matrix to B.C. Axes is the Point Record #LMN
40	INTP	-Kinematic Dependency Pointer to Interface File if NU>0, and NEP<NU≤NEP+NDP -Kinematic dependency pointer to Dependency File if NU>0, and NU>NEP+NDP -Pointer to User Number of Merge Node if NU<0
41	NLDREC	Pointer to Point Load in dataset 'PLD'
42	NBL	Number of Corresponding Unknown Block
43	NFR	Relative Number of First Unknown Within Block

Data Set: PTS (Continued)

Location	Variable	Description
44	MFP	Map of Freedom Pattern, Packed into the Lower-order Twelve Bits. From the Highest Order Bit, they are L(1) - L(6): Freedom Flags 0 - Suppressed 1 - Allowed L(7) - L(12): Prescribed Displacement Flags 0 - Freedom not Prescribed 1 - Freedom Prescribed (Displacement Values are stored in 'LDS' data set) (The values may be packed by Library Subroutine PKF(L,MFP) and unpacked by Library Subroutines UPF(MFP,L), UPF1(MFP,L,N)

Data Set: PTS (For Boundary Condition Points)

Location	Variable	Description
1	NU	= 32767 (Boundary Condition Point Flag)
2	NS	System Node Number for User Node 'I'
3	ISTRKT	= 0
4	IPTPLT	Plot Indicator
5-22	DC(3,3)	Direction Cosines of Local Axes (Unimplemented)
23-38	WRKPAD(8)	Scratch Space
39	NLEL	Pointer to Lagrange Element (if any)
40	NPTD	User Node Number for which this is a B.C. point
41	IFREE	Unused
42	NBL	Number of Corresponding Unknown Block
43	NFR	Relative Number of First Unknown Within Block
44	MFP	Map of Freedom Pattern (same as before)

ELT

Type	;	Random Access
Status	;	Permanent, INTS

Data Size Parameters	;	IPRS = 450 (words)
		IBF = 10
		LRS = 45

Data Set Description. This data set contains element generation logic. Each logical record contains user and system element numbers for each element. Same variables are stored for every element type up to 11th location. Different variables are used for substructured element and Lagrange element from the 12th location. In the case that number of corner points are more than 8, the continuation records are stored in the next logical record space. For continuation records:

1	NEU	= -32767
2-35	LCPCON(34)	= List of Corner Points (continued)
36-45	-	= Unused

LOGICAL RECORD CONTENTS (25 integer + 10 floating point)

Data Set: ELT

Location	Variable	Description
1	NEU	User Element Number
2	NFS	System Element Number for User Element 'I'
3	ISTRKT	Structure Flag (= ITY + 8*N)
		ITY = 0 - Unassociated Element
		= 1 - Unused
		= 2 - Contained in Line #N
		= 3 - Contained to Grid #N
		= 4 - Contained in Solid #N

Data Set: ELT (Continued)

Location	Variable	Description
4	IELPLT	Plot Indicator
		=0 - Don't Plot
		=1 - Plot
5	IT	Element Type
		= 1 - ROD/ASM
		= 2 - BEAM/AXP
		= 3 - TM/TA
		= 4 - TB
		= 5 - QM/QA
		= 6 - QB
		= 7 - TET
		= 8 -SLD
		=10 - SPRING IORD = 1; SPRING IORD = 2; TSPRING
		=11 - LAGRANGE MULT. ELEMENT IORD = 1; DISPLACEMENT IORD = 2; CONSTRAINT
6	IORD	Element Deflection Interpolation Order
		= 1 - Linear
		= 2 - Parabolic
		= 3 - Cubic
7	IST	Element Sub-Type
		= 0 - Plane Stress
		= 1 - Plane Strain
		= 2 - Axisymmetric
8	IAPL	Element Mode
		= 0 - Stiffness, Stress and Display
		= 1 - Stress and Display
		= 2 - Display Only
		= 3 - Pseudo Element
9	NLDREC	Pointer to Load Record in data set 'ELD'
10	NCP	Number of Corner Points
11	NGP	Total Number of Points

Data Set: ELT (Continued)

Location	Variable	Description

12	NLFLG	Nonlinearity Flags (2*NLGFLG+NLMFLG)
		NLGFLG = 0 - No Geometric Nonlinearity
		NLGFLG = 1 - Geometric Nonlinearity
		NLMFLG = 0 - No Material Nonlinearity
		NLMFLG = 1 - Material Nonlinearity

13	NSTPT	Number of Stress Points per Layer
14	NLAYR	Number of Layers for which Stresses Exist
15	ISTPTR	Pointer to First Record in Stress data set 'STR'
16	NMAT	Material Type Number = 1 - Isotropic = 2 - 1-D Orthotropic (Fibers) = 3 - 1-D Orthotropic (Smeared Stiffner) = 4 - 2-D Orthotropic = 5 - Nonlinear = 6 - Temperature Dependent = 7 - Composite
17	NTHS	Thickness Group Number
18-19	FACM1	Material Interpolation Factors in 2-Directions
20-21	FACM2	
22-23	FACT1	Thickness Interpolation Factors in 2-Directions
24-25	FACT2	
26-27	ALPHA	Angle Between Element Side 1-2 and Material Axis (Orthotropic Material only -- Currently Unused)
28-29	ECCEN	Eccentric Offset to Attachment Point (along Local Coord. System Z-Axis) from Center of Element's Thickness (only for Shell Elements)
30-35	WRKPAD(3)	Scratch Space
36-37	ALPHID	Alphanumeric Identifier
38-45	LCP(8)	List of Corner Points (by System Number)

Data Set: ELT (For Sub-Structure Elements)

Location	Variable	Description
1-11	-	Same as Before
12-15	IFREE(4)	Unused
16	IPLTSW	Special Plot File Indicator = 0 - None Exists = 1 - Special File 'CPF' Exists
17	NFILCS	Number of Files in COSUB Model (Used by STIFF)
18-21	RNAME(2)	COSUB Name
22-23	SCF	Stiffness Scale
24-25	SCL	Load Scale
26-29	FREE(2)	Unused
30-35	WRKPAD(3)	Scratch Space
36-37	ALPHID	Alphanumeric Identifier
38-45	LCP(8)	List of Corner Points (by System Number)

Data Set: ELT (For Lagrange Elements)

Location	Variable	Description
1-11	-	Same as Before
12-14	IFREE(3)	Unused
15-17	LF(3)	Packed Freedom Numbers for Constraint Elements (Two Freedoms per Integer)
18-29	FILL(6)	Sufficient Space Left to Occupy 5 floating pt. Numbers and Remainder of One Equivalenced LF(3)
30-35	WRKPAD(3)	Scratch Space
36-37	ALPHID	Alphanumeric Identifier
38-45	LCP(8)	List of Corner Points (by System Number)

SUR

Type	;	Random Access
Status	;	Permanent, INTS

Data Size Parameters	;	IPRS = 325 (words)
		IBF = 5
		LRS = 65

Data Set Description. This data set contains the definition of mathematical 3-D surfaces of up to third order to which lines and grids may be projected. The surfaces are defined in some local coordinate system. Each logical record consists of 32 floating point and 1 integer values.

LOGICAL RECORD CONTENTS (32 floating point + 1 integer)

Location	Variable	Description
1-18	ROT(3,3)	Coord. Rotation Matrix (Local to Global)
19-24	TRAN(3)	Coord. Translation Matrix (Local to Global)
25-64	COEF(20)	Coeff. of General 3-D Cubic Surface in Local Coord. to which LINES or/and Grids may be Projected after Generation
65	IORD	Order of Surface (1, 2 or 3)

SLI

Type	;	Random Access
Status	;	Permanent, INTS

Data Size Parameters	;	IPRS = 180 (words)
		IBF = 10
		LRS = 18

Data Set Description. This data set contains the slice element generation logic for BULKS Module.

Logical Record Contents (18 integer)

Location	Variable	Description
1	NEL	Element Number (if Element Slice)
2	NSLD	Solid Number = 3 - TM (Point Slice) = 5 - QM (Point Slice) = 7 - TET (Element Slice) = 8 - SLD (Element Slice)
4	IORD	Element Order = 1 - Linear Interpolation = 2 - Parabilic Interpolation = 3 - Cubic Interpolation
5	NCP	Number of Attachment Point
6-9	LELT(4)	List of Adjustment Elements (if point slice)
10	NMAT	Material Number (if Element Slice)
11-18	LCP(8)	List of Corner Points (by System Number)

LIN

Type	;	Random Access
Status	;	Permanent, INTS

Data Size Parameters	;	IPRS = 490 (words)
		IBF = 10
		LRS = 49

Data Set Description. This data set contains the line generation logics for 7 different types of lines

1. Straight Line 2. Circular Arc 3. Parabolic Arc 4. Cubic Arc
5. Composite Line 6. Arbitrary Line 7. Plot Line

For line types 1-4, same variables are stored in the logical records. For line type 5-7, the different types of variables are stored.

LOGICAL RECORD CONTENTS (9 floating point + 31 integer)

Location	Variable	Description
1-4	XNAME(2)	Line Name (Up to 8 Characters)
5-16	BOX(2,3)	Min. and Max. Coord. Limits in 3 Axes
17-18	ALPHID	Alphanumeric Element Identifier
19	NSURF	Number of Surfaces to which LINE is to be Projected (Max. 2)
20-21	LSURF(2)	List of Surfaces to Which Line is to be Projected
22	LINPLT	Plot Indicator = 0 - Don't Plot = 1 - Plot
23	LINTYP	Line Type = 1 - Straight Line = 2 - Circular Arc = 3 - Parabolic Arc = 4 - Cubic Arc = 5 - Composite Line = 6 - Arbitrary Line = 7 - Plot Line: same as Arbitrary Line, Except not Allowed as Grid Boundary
24	LINGEN	Generation Status = 0 - Not Generated = 1 - Generated

Data Set: LIN (For Line Types 1-4)

Location	Variable	Description
25	NG	Number of Grids to Which Line is Attached
26-33	LG(8)	List of Attached Grid Numbers
34	NPTS	Total Number of Internal Points
35	NFP	User Number of First Internal Point
36	IBTYP	Bias Type
		= 0 - None
		= 1 - End
		= 2 - Center
37	IBIAS	Bias Value (Integer -1000 to +1000)
		$\frac{L(I)}{L(I+1)} = 1 + \frac{IBIAS}{100}$ For IBIAS > 0
		$\frac{L(I+1)}{L(I)} = 1 - \frac{IBIAS}{100}$ For IBIAS < 0
38	IELTY	Element Type
		= 0 - None
		= 1 - Truss
		= 2 - Beam
39	IORD	Order of Element (>1 for Higher Order)
40	IELSTY	Element Sub-Type + 100*Application No.
41	NELTS	Number of Elements
42	NFEL	Number of First Elements
43	NGP	Number of Geometric Point (for Beam)
44	NMAT	Element Material Type Number
45	NTHS	Element Thickness Group Number
46-49	LKP(4)	List of Key Points Defining the Line

Data Set: LIN (For Line Type 5: Composite Line)

Location	Variable	Description
25	NG	Number of Grids to Which Line is Attached
26-33	LG(8)	List of Attached Grid Numbers
34	NPTS	Total Number of Internal Points
35	NFP	User Number of First Internal Point
36	NL	Number of Lines in Composite (Max. 9)
37-45	LL(9)	List of Numbers of Lines Forming Composite
46-47	LKP(2)	List of End Points of the Line
48-49	IFREE(2)	Unused

NOTE. A sequentially numbered series of nodes is generated for the internal nodes of a composite line. These nodes are then automatically merged into the corresponding nodes of the lines comprising the composite.

Data Set: LIN (For Line Type 6: Arbitrary Line)

Location	Variable	Description
25	NG	Number of Grids to Which Line is Attached
26-33	LG(8)	List of Attached Grid Numbers
34	NPTS	Total Number of Internal Points
35	NFP	User Number of First Internal Point
36	NP	Number of Points in Line (Max. 9)
37-45	LPC(9)	List of User Numbers of Points Forming Line
46-47	LKP(2)	List of End Points of the Line
48-49	IFREE(2)	Unused

NOTE. A sequentially numbered series of nodes is generated for the internal nodes of an arbitrary line. These nodes are then automatically merged into the corresponding nodes of the series defined by the user.

Data Set: LIN (For Line Type 7: Plot Line)

Location	Variable	Description
25-33	IFREE(9)	Unused
34	NPTS	Total Number of Internal Points
35	NFP	User Number of First Internal Points
36	NP	Number of Points in Line (Max. 9)
37-45	LP(9)	List of User Numbers of Points Forming Line
46-47	LKP(2)	List of End Points of the Line
48-49	IFREE(2)	Unused

NOTE. A sequentially numbered series of nodes is generated for the internal nodes of a plot time. These nodes are then merged automatically into the corresponding nodes of the series defined by the user.

THS

Type	;	Random Access
Status	;	Permanent, INTS

Data Size Parameters	;	IPRS = 180 (words)
		IBF = 5
		LRS = 36

Data Set Description. This data set consists of one record group (one or more records) for every element geometric data group. The first record in the group contains the list of element property values (cross-sectional area, thickness, etc.) needed during stiffness generation, while the following records (if any) contain the user's definition of the group (cross-sectional dimensions of a beam, etc.).

Logical Record Contents. (6 integer + 15 floating point) In general, record #I contains its first record number and the remainder of each record is dependent upon the value of 'ITYPE'.

Data Set: THS (For ITYPE = 0)

Location	Variable	Description
1	ITHPTR	First Record Number of Thickness Group Number 'I' (zero if Thickness Group #I Nonexistent)
2	ITYPE	Thickness Group Type (= 0) (Simple Value List)
3	IPTRCS	Pointer to Record in this Data Set at Which Standard Element Cross-Section Definiton is Stored (0 = None)
4	LRED	Color Levels
5	LGREEN	
6	LBLUE	
7-36	THS(15)	List of Element Properties - TRUSSES: AREA - Cross Sectional Area FREE(14) - Unused - BEAMS: AREA - Cross Sectional Area AQ AP Areas effective in shear IPP - Major Moment of Inertia IQQ - Minor Moment of Inertia RJ - Torsional Moment of Inertia PG1 Coord. of Centroid Relative QG1 to Att. Point 1. PGZ Coord. of Centroid Relative QGZ to ATT. Point 2 P01 Coord. of Shear Center Q01 Relative to Att. Point 1 P02 Coord. of Shear Center Q02 Relative to Att. Point 2

Data Set: THS (For ITYPE = 0) (Continued)

Location	Variable	Description
7-36	THS(15)	- TM/TA; T - Thickness
		FREE(14) - Unused
		- QM/QA; T - Thickness
		FREE(14) - Unused
		- TB/QB; T - Thickness
		BETA - Pseudo In-Plane Rotational Stiffness Factor (cf. Theoretical Manual) BETA < 0 - None BETA = 0 - Use Default of 0.2 BETA > 0 - Use BETA

Data Set: THS (For ITYPE = 1)

Location	Variable	Description
1	ITHPTR	First Record Number of Thickness Group Number 'I'
2	ITYPE	Thickness Group Type (=1) (Interpolation Value List)
3	IPTRCS	Same as that for ITYPE = 0
4	LRED	Colour Levels
5	LGREEN	
6	LBLUE	
7-12	THS1(3)	Element Properties at Corner #1 (Double) or Endpoint #1 (Single)
13-18	THS2(3)	Element Properties at Corner #2 (Double) or Endpoint #1 (Single)
19-24	THS3(3)	Element Properties at Corner #3 (Double) or Endpoint #2 (Single)
25-30	THS4(3)	Element Properties at Corner #4 (Double) or Endpoint #2 (Single)
31-36	FREE(3)	Unused

Data Set: THS (For ITYPE = 2)

Location	Variable	Description
1	ITHPTR	First Record Number of Thickness Group Number 'I'
2	ITYPE	Thickness Group Type (=2) (Geometric Data is to be Interpolated from the Following Two Cross-Section Definitons Stored with this Thickness Group.)
3	IPTRCS	Pointer to Record in this Data Set at Which Geometric Interpolation Data is Stored
4	LRED	
5	LGREEN	Color Levels
6	LBLUE	
7-36	FREE(15)	Unused

Data Set: THS (For ITYPE = 3)

Location	Variable	Description
1	ITHPTR	First Record Number of Thickness Group Number 'I'
2	ITYPE	Thickness Group Type (= 3) (Cross-Section Definition)
3	IPTRCS	Same as That for ITYPE = 0
4	ICSTYP	Standard Cross-Section Type = -7 - Continuation of Arbitrary Polygon Beam = 1 - Solid Rectangluar Beam = 2 - Hollow Rectangular Beam = 3 - Solid Rectangular Beam = 4 - Hollow Circular Beam = 5 - General I-Beam = 6 - Oblique Angle (Beam) = 7 -Arbitrary Polygon Beam
5-6	IFREE(2)	Unused

Data Set: THS (For ITYPE = 3) (Continued)

Location	Variable	Description
7-32	BMDIM(13)	Cross-Section Dimensions - For 'ICSTYP' = 1: Solid Rectangular Beam H - Beam Height B - Beam Width FREE(6) - Unused ZA1 YA1 Coord. of Attachment Points ZA2 Relative to Beam Center YA2 THETA - Orientation Angle of Beam, Relative to Third (Geometric) Point (Degree) - For 'ICSTYP' = 2: Hollow Rectangular Beam H - Beam Height B - Beam Width TH - Side Wall Thickness TB - Top and Bottom Wall Thickness FREE(4) - Unused ZA1 YA1 Coord. of Attachment Points, ZA2 Relative to Beam Center YA2 THETA - Orientation Angle of Beam, Relative to Third (Geometric) Point in Degrees

Data Set: THS (For Type = 3) (Continued)

Location	Variable	Description
7-32	BMDIM(13)	Cross-Section Dimensions - For 'ICSTYP' = 3: Solid Circular Beam R - Beam Radius FREE(7) - Unused ZA1 YA1 Coord. of Attachment Points, ZA2 Relative to Beam Center YA2 FREE - Unused - For 'ICSTYP' = 4: Hollow Circular Beam RO - Outer Radius RI - Inner Radius FREE(6) - Unused ZA1 YA1 Coord. of Attachment Points, ZA2 Relative to Beam Center YA2 FREE - Unused - For 'ICSTYP' = 5: General I-Beam H - Web Height B1 - Upper Flange Width B2 - Lower Flange Width TW - Web Thickness T1 - Upper Flange Thickness T2 - Lower Flange Thickness E1 - Upper Flange Offset (From Center of Web to Center of Flange) E2 - Lower Flange Offset

Data Set: THS (For ITYPE = 3) (Continued)

Location	Variable	Description
7-32	BMDIM(13)	Cross-Section Dimensions
		ZA1 YA1 Coord. of Attachment Points, ZA2 Relative to Bottom-Center of Web YA2 THETA - Orientation Angle of Beam, Relative to Third (Geometric) Point in Degrees
7-32	BMDIM(13)	Cross-Section Dimensions
		For 'ICSTYP' = 6: Oblique Angle Beam B - Width of Flanges T - Thickness of Flanges PHI - Angle Between Flanges in Degrees FREE(5) - Unused ZA1 YA1 Coord. of Attachment Points, ZA2 Relative to Beam's Appex. YA2 (Y-Axis bisects the Angle) THETA - Orientation Angle of Beam, Relative to Third (Geometric) Point in Degrees
		For 'ICSTYP' = 7: Arbitrary Polygon Beam <First Record> NPTS - Number of Corner Points NWALLS - Number of Walls NCELLS - Number of Closed Cells FREE(5) - Unused ZA1 YA1 Coord. of Attachment Points ZA2 with Respect to Local Origin YA2 THETA - Orientation Angle of Beam

Data Set: THS (For ITYPE = 3) (Continued)

Location	Variable	Description
7-32	BMDIM(13)	Cross-Section Dimensions
		<Second Record>
		Z1,Y1 - Coord. of Corner 1 with respect to Att. Pt.
		Z2,Y2 - Coord. of Corner 2 with respect to Att. Pt.
		Z3,Y3 - Coord. of Corner 3 with respect to Att. Pt.
		Z4,Y4 - Coord. of Corner 4 with respect to Att. Pt.
		Z5,Y5 - Coord. of Corner 5 with respect to Att. Pt.
		Z6,Y6 - Coord. of Corner 6 with respect to Att. Pt.
		FREE - Unused
		For 'ICSTYP' = -7: Continuation Records 1
		VC(2,6) - Coord. (Z,Y) of up to 6 more corner points
		FREE - Unused
		For 'ICSTYP' = -7: Continuation Records 2
		S11,S21 - 2 Endpoints of Side 1
		S12,S22 - 2 Endpoints of Side 2
		S13,S23 - 2 Endpoints of Side 3
		S14,S24 - 2 Endpoints of Side 4
		T1 - Thickness of Side 1
		T2 - Thickness of Side 2
		T3 - Thickness of Side 3
		T4 - Thickness of Side 4
		FREE - Unused
		For 'ICSTYP' = -7: Continuation Records 3
		S1J,S2J - 2 Endpoints of Side J
		S1K,S2K - 2 Endpoints of Side K
		S1L,S2L - 2 Endpoints of Side L
		S1M,S2M - 2 Endpoints of Side M
		TJ - Thickness of Side J
		TK - Thickness of Side K
		TL - Thickness of Side L
		TM - Thickness of Side M
		FREE - Unused

Data Set: THS (For ITYPE = 3) (Continued)

Location	Variable	Description
		For 'ICSTYP' = -7: Continuation Records 4
		LCC1(13) - List of Cell Corners for Closed Cell Number I.
		LCWI(13) - List of Closed Cell Walls for Cell Num.
33-36	FREE(2)	Unused

MAT

Type	;	Random Access
Status	;	Permanent, INTS

Data Size Parameters	;	IPRS = 135 (words)
		IBF = 5
		LRS = 27

Data Set Description. This data set contains material property data. Eight different types of materials can be handled.

Logical Record Contents (5 integer + 11 floating point)

Location	Variable	Description
1	MATPTR	First Record Number of Material Number 'I' (Zero if Material #I Non-existant)
2	IMT	Material Type 1 - Isotropic Material 2 - 1-D Orthotropic Material (Fibers) 3 - 1-D Orthotropic 'Smeared Stiffner' 4 - 2-D Orthotropic Material 5 - Nonlinear Material 6 - Temperature Dependent Material 7 - Composite Material 8 - Interpolation List <0 - Continuation Record (Negative of Material Type being Represented)
3	LRED	
4	LGREEN	Color Levels
5	LBLUE	

Data Set: MAT (For IMT = 1)

Location	Variable	Description
6-7	E	Young's Modulus
8-9	VNU	Poisson's Ratio
10-11	G	Shear Modulus
12-13	SY	Yield Stress (Von-Mises Criterion)
14-15	RHO	Mass Density
16-17	C	Damping Coefficient per Unit Volume
18-19	ALPHA	Thermal Expansion Coefficient
20-21	U	Thermal Conductivity
22-23	TEMP	Temperature
24-25	CV	Specific Heat (at Constant Volume) (May be used as Specific Heat at Constant Pressure, etc.)
26-27	H	Enthalphy

Data Set: MAT (For IMT = 2)

Location	Variable	Description
6-7	E	Young's Modulus (of Layer)
8-9	PCKDEn	Packing Density (Fraction of Layer Cross-Sectional Area Taken up by Fibers)
10-11	FREE	Unused
12-13	SY	Yield Stress (Tension)
14-15	RHO	Mass Density (of Layer)
16-17	C	Damping Coeff. per Unit Volume
18-19	ALPHA	Thermal Expansion Coefficient
20-21	U	Thermal Conductivity
22-23	TEMP	Temperature
24-25	CV	Specific Heat
26-27	H	Enthalphy

Data Set: MAT (For IMT = 3)

Location	Variable	Description
6	NMAT	Pointer to Mat. Definition for the Smeared Stiffners
7	NTHS	Pointer to Cross-Section Properties for Individual Beam Comprising the Smeared Stiffners in 'THS'
8-9	SPACING	Beam Spacing (Distance Between Rows of Beams)
10-11	THETA	Angle from Mat.Plane to Individual Beam's Ref.Plane
12-13	OFFSET	Offset from Material's Reference Plane to Beam's Attachment Point
14-27	FREE(7)	Unused

Data Set: MAT (For IMT = 4 and IMT = -4)

Location	Variable	Description
6-7	E1	Young's Modulus in Principal Direction
8-9	VNU1	Poisson's Ratio in Principal Direction
10-11	G	Shear Modulus
12-13	SY1	Yield Stress in Principal Direction
14-15	RHO	Mass Density
16-17	C	Damping Coefficient per Unit Volume
18-19	ALPHA1	Thermal Expansion Coeff. (Principal Direction)
20-21	U1	Thermal conductivity (Principal Direction)
22-23	TEMP	Temperature
24-25	CV	Specific Heat
26-27	H	Enthalpy
6-7	E2	Young's Modulus in Minor Direction
8-9	VNU2	Poisson's Ratio in Minor Direction
10-11	SHRYLD	Shear Yield Stress
12-13	SY2	Yield Stress in Minor Direction
14-17	FREE(2)	Unused
18-19	ALPHA2	Thermal Espansion Coeff. (Minor Direction)
20-21	U2	Thermal Conductivity (Minor Direction)
22-26	FREE(3)	Unused

Data Set: MAT (For IMT = 5: First Record)

Location	Variable	Description
6	NSEG	Number of Linear Segments in Approximation
8	NREC	Number of Records Needed to Represent Material (NSEG+1)
9-21	FREE(6)	Unused
22-23	TEMP	Temperature
24-27	FREE(2)	Unused

NOTE. For a nonlinear material NSEG+1 records are needed. Each linear segment is defined as an isotropic (IMT = -1) or 1-D orthotropic (IMT = -2) material, with yield stress replaced by strain value at end of segment. (First segment starts at zero.)

Data Set: MAT (For IMT = 6; First Record)

Location	Variable	Description
6	NTEMP	Number of Temperature Values at Which Properties are Defined, and Between Which to Interpolate
8	NREC	Number of Records Needed to Represent Material
10-27	FREE(9)	Unused

NOTE. For a temperature dependent material several records are needed. Temperature dependent material may be defined from any of the previously described material types. Properties at temperature value must be defined in the succeeding records:

- ISOTROPIC -- IMT = -1, NTEMP Records
- 1-D ORTHOTROPIC -- IMT = -2, NTEMP Records
- GENERAL ORTHOTROPIC -- IMT = -4, NTEMP Record Pairs
- NONLINEAR -- IMT = -5, NTEMP Groups

Data Set: MAT (For IMT = 7; First Record and NCOMP Record)

Location	Variable	Description
6	NCOMP	Number of Component Layers (Matrices and Fibers)
7	NREC	Number of Records to Represent Material (NCOMP+1)
8-27	FREE(9)	Unused
6	LYRPTR	Pointer to Material (ISotropic or 1-D Orthotropic -- including Linear, Nonlinear and Temp. Dependent) Comprising the Layer

Data Set: MAT (For IMT = 7; First Record and NCOMP Record) (Continued)

Location	Variable	Description
7-8	THRFB	Fraction of Composite Material Thickness at Which Layer Begins (Bottom of Layer)
9-10	THFRT	Fraction of Composite Material Thickness at Which Layer Ends (Top of Layers) NOTE: THFRB and THFRT vary from 0 to 1 where 0 = Bottom 1 = Top
11=12	GAMMA	Angle (in Radians) Between Composite Reference Axis and 1-D Orthotropic Material Axis (Measured C.C.W as Viewed from Material Top)
13-27	FREE(7)	Unused

NOTE. For a composite material several records are needed. Composite material may be made of nonlinear and temperature dependent components. It is not required that all layers be nonlinear or temperature dependent simultaneously.

Data Set: MAT (For IMT = 8)

Location	Variable	Description
6	ITYPE	Interpolation List Type = 1 - Linear Interpolation Between Materials MAT1 and MAT2 = 2 - Bi-linear Interpolation From Materials MAT1, MAT2, MAT3 and MAT4 During Interpolation, Direction 1 will be Defined as from Edge 1-3 to Edge 2-4. Direction 2 will be Defined as from Edge 1-2 to Edge 3-4.
8	MAT1	Pointer to Previously Defined Material #1
10	MAT2	Pointer to Previously Defined Material #2
12	MAT3	Pointer to Previously Defined Material #3
14	MAT4	Pointer to Previously Defined Material #4
16-27	FREE(6)	Unused

NOTE. An interpolation list description consists of a header record which points to material descriptions at the boundaries of the interpolation region. All of the specified material definitions must be of the same type, varying only in the values of the assorted material properties.

GRD

Type ; Random Access

Status ; Permanent, INTS

Data Size Parameters ; IPRS = 315 (words)
IBF = 5
LRS = 63

Data Set Description. This data set contains grid generation logic. Stored data are dependent on grids to be generated.

Logical Record Contents (43 ingeter + 10 floating point)

Location	Variable	Description
1-4	GNAME(2)	Grid Name (Up to 8 Characters)
5-16	BOX(2,3)	Min. and Max. Coord. Limits in 3 Axes
17-18	ALPIDL	Line Element Alphanumeric Identifier
19-20	ALPIDG	Grid (Surface) Element Alphanumeric Identifier
21	LRED	
22	LGREEN	Colour Levels
23	LBLUE	
24	NSURF	Surface Number of Which Grid is to be Projected
25	IGDPLT	Plot Indicator
26	IFTYPE	Grid Type:
		1 - Parametric Grid (GRID4)
		2 - Parabolic Isoparametric Grid (GRIDP)
		3 - Parabolic Isoparametric Grid (GRIDC)
		4 - Triangular Grid (GRID3)
		5 - Transition Grid (GRIDT)
		6 - Composite Grid (COMPGRID)
		7 - Arbitrary Grid (ARBGRID)

Data Set: GRD (For IGTYPE = 1 - 3)

Location	Variable	Description
27	IGDGEN	Generation Status
		=0 - Grid not Generated
		=1 - Grid Generated
28	NPTS	Number of Internal Points
29	NFP	User Number of First Internal Poirt
30	ISETY	Surface Element Type (3,4,5,6) + 100*SUBTYPE (0,1,2)
31	IORDS	Surface Element Order + 100*Application
32	ISTDIR	Stiffner Direction
		=0 - No Stiffners
		=1 - Stiffners Parallel to Sides 1 and 3
		=2 - Stiffners Parallel to Sides 2 and 4
		=3 - Sitffners Parallel to Sides 1&3 and 2&4
33	ILETY	Line (Stiffner) Element Type (1,2) + 100*SUBTYPE (0,1,2)
34	IORDL	Line Element Order + 100*Application
35	NELTS	Number of Elements
36	NFEL	Number of First Element
37	NMATLS	Surface Element Material Type Number
38	NTHSS	Surface Element Geometric Data Number
39	NMATLL	Line Element Material Type Number
40	NTHSL1	Geometric Data Number of Stiffners
41	NTHSL2	Parallel to 1&3 and 2&4
42	NSP	Number of Attached Surfaces
43-44	LSP(2)	List of Attached Surfaces
45-56	LDAT(3,4)	Information about Edges for each Edge:
		LDAT(1,I) - Line Number
		LDAT(2,I) - First Internal Point Number
		LDAT(3,I) - Internal Point Number Increment
57-60	LCP(4)	List of Corner Point Numbers
61-62	MM,NN	Number of Divisions in the Two Directions
63	NGP	'GRIDC' Center Point Number

Data Set: GRD (For IGTYPE = 4)

Location	Variable	Description
27	IGDEN	Generation Status
		=0 - Grid not Generated
		=1 - Grid Generated
28	NPTS	Number of Internal Points
29	NFP	User Number of First Internal Point
30	ISETY	Surface Element Type (3,4) + 100*SUBTYPE (0,1,2)
31	IORDS	Surface Element Order + 100*Application
32	ISTDIR	Stiffner Direction
		=0 - No Stiffners
		=1 - Parallel to Side 1
		=2 - Parallel to Side 2
		=3 - Parallel to Side 3
33	ILETY	Line (Stiffner) Element Type (1,2) + 100*SUBTYPE (0,1,2)
34	IORDL	Line Element Order + 100*Application
35	NELTS	Number of Elements
36	NFEL	Number of First Element
37	NMATLS	Surface Element Material Type Number
38	NTHSS	Surface Element Geometric Data Number
39	NMATLL	Line Element Material Type Number
40	NTHSL	Line Element Geometric Data Number
41	IFREE	Unused
42	NSP	Number of Attached Surfaces
43-44	LSP(2)	List of Attached Surfaces
45-56	LDAT(3,4)	Information About Edges for each Edge:
		LDAT(1,I) - Line Number
		LDAT(2,I) - First Internal Point Number
		LDAT(3,I) - Internal Point No. Increment
57-60	LCP(4)	List of Corner Point Numbers
61	MM	Number of Divisions in the Two Directions
62	NN	
63	IFREE	Unused

Data Set: GRD (For IGTYPE = 5, 6 and 7)

Location	Variable	Description
27	IGDEN	Generation Status =0 - Grid not Generated =1 - Grid Generated
28	NPTS	Number of Internal Points
29	NFP	User Number of First Internal Point
30	ISET	Surface Element Type (3,4,5,6) + 100*SUBTYPE (0,1,2)
31	IORDS	Surface Element Order + 100*Application
32	ISTDIR	Stiffner Direction (=0)
33-34	IFREE(2)	Unused
35	NELTS	Number of Elements (Surface Only)
36	NFEL	Number of First Element
37	NMATLS	Surface Element Naterial Type Number
38	NTHSS	Surface Element Geometric Data Number
39-41	IFREE(3)	Unused
42	NSP	Number of Attached Surfaces
43-44	LSP(2)	List of Attached Surfaces
45-56	LDAT(3,4)	Information about Edges. For Each Edge: LDAT(1,I) - Line Number LDAT(2,I) - First Internal Point Number LDAT(3,I) - Internal Point Number Increment
57-60	LCP(4)	List of Corner Point Numbers
61-62	MM,NN	Number of Divisions in the Two Directions
63	IFREE	Unused
- - -	- - -	- - -
27	NS	Number of Grids Forming Composite (Max. 36)
28-63	LS(36)	List of Record Numbers of Grids
- - -	- - -	- - -
27	NELST	Number of Element Strings in Surface (Max. 18)
28-63	LELT(2,18)	List of Element Strings. For String 'I' LELT(1,I) - First Element in String LELT(2,I) - Last Element in String

SLD

Type ; Random Access

Status ; Permanent, INTS

Data Size Parameters ; IPRS = 147 (words)
IBF = 1
LRS = 147

Data Set Description. This data set contains solid element generation logic. Five different types of solid element can be handled.

Logical Record Contents (129 integer + 9 floating point)

Location	Variable	Description
1-4	SNAME(2)	Solid Name (up to 8 Characters)
5-16	BOX(2,3)	Min. and Max. Coord. Limits in 3 Axes
17-18	ALPHID	Alphanumeric Element Identifier
19	LRED	
20	LGREEN	Color Levels
21	LBLUE	
22	ISLPLT	Plot Indicator =0 - Don't Plot =1 - Plot
23	ISLTYP	Solid Grid Type =0 - Cube (6 Sides - 8 Corners) =1 - Prism (5 Sides - 6 Corners) =2 - Pyramid (5 Sides - 5 Corners) =3 - Tetrahedron (4 Sides - 4 Corners) =4 - Composite =5 - Arbitrary

Data Set: SLD (For ISLTYP = 0 - 3)

Location	Variable	Description
24	ISLGEN	Generation Indicator:
		=0 - Solid Not Generated
		=1 - Solid Generated
25	NPTS	Number of Internal Points
26	NFP	User Number of First Internal Point
27	IELTY	Element Type (7,8)
28	IELORD	Element Order
		=1 - Linear
		=2 - Parabolic
		=3 - Cubic
29	NELTS	Number of Elements
30	NFEL	Number of First Element
31	NMATL	Element Natrial Type Number
32-76	ISLICE(5,9)	Information up to 9 Slices
		Each Column of LSLICE(5,9) Contains
		1 - Slice Type; 1 = Point, 2 = Element
		2 - Face No. from Which Slice is Offset
		3 - Layer No. (1 = Face)
		4 - Record No. in 'SLI' at Which Slice Elements Begin
		5 - No. of Slice Elements
77-100	LGDAT(4,6)	Grid Data up to 6 Faces. Each Column Contains
		1 - Surface Number
		2 - Starting Internal Point Number
		3 - Internal Point No. Increment in Direction 1
		4 - Internal Point No. Increment in Direction 2
101-136	LDAT(3,12)	Edge Data up to 12 Edges. Each Column Contains
		1 - Line Number
		2 - First Internal Point Number
		3 - Increment of Internal Point Numbers
137-144	LCP(8)	List of Corner Point Numbers (Max. 8)
145-147	LL,MM,NN	Total No. of Points in Three Directions

Data Set: SLD (For ISLTYP = 4)

Location	Variable	Description
24	NSLD	No. of Solid Grids Comprising Composite
25-147	LSLD(123)	List of Numbers of Solids Comprising Composite (Max. 123)

Data Set: SLD (For ISLTYP = 5)

Location	Variable	Description
24	NELST	No. of Element Strings in Solid (Max. 61)
25-146	LELT(2,61)	List of Element Strings. For String 'I': LELT(1,I) - First Element in String LELT(2,I) - Last Element in String
147	IFREE	Unused

4.6.3 Static Analysis Group

After model is generated, loads and kinematic boundry conditions are specified. To perform a static analysis, first the bandwidth must be optimized to ensure efficient computation. Then the stiffness matrix is computed and decomposed. Finally, deflections and stresses are obtained. The following data sets are generated during the static analysis.

PLD

Type ; Random Access

Status ; Permanent, INTS

Data Size Parameters ; IPRS = 220 (words)
IBF = 10
LRS = 22

Data Set Description. This data set contains load values for each node and each loading case. Any node may have more than one logical record. The loads are flagged as conservative or non-conservative and are linked together. If both types of loads occur for the node, they will be in the order of conservative, nonconservative.

Logical Record Contents (6 integer + 8 floating point)

Location	Variable	Description
1	NP	User Node Number
2	NLC	Loading Case Number
3	ITYPE	Load Type Indicator =0 - Conservative Loads =1 - Non-conservative Loads
4	IPTR	Pointer to Additional Records Defining Current Loading Case: = 0 - No Additional Loads >0 - Load Definition Continues in Logical Record #IRTR
5	LCPTR	Pointer to Record with Loads for Next Loading Case
6	NNLC	Next Loading Case Number
7-18	VLD(6)	Load Values by Component
19-20	RES	Load Resulant
21-22	RESM	Moment Resultant

NOTE. Each node record in 'PTS' has a pointer to the first record in this data set. Multiple loading cases for a single node are chained together in ascending order by loading case. The last record for one node has a pointer of zero.

ELD

Type ; Random Access

Status ; Permanent, INTS

Data Size Parameters ; IPRS = 350 (words)
IBF = 5
LRS = 70

Data Set Description. This data set contains load values for each element and each loading case. Any element may have more than one logical record. The loads are flagged as conservative, non-conservative pressure, straight acceleration or centripetal acceleration and linked together. If multiple types of loads occur in one loading case, they will be stored in the order of conservative, straight acceleration, centripetal acceleration, and non-conservative pressure. The only type of non-sonservative load supported at present is non-conservative pressure.

Each element record in 'ELT' has a pointer to the first record in this data set. Elements with no loads have no record in this data set. Elements with no loads have no records in 'ELD'. Multiple loading cases for a single element are chained together in ascending order by loading case. The last record has a pointer of zero.

Logical Record Contents (6 integer + 32 floating point)

Location	Variable	Description
1	NEL	User Element Number
2	NLC	Loading Case Number
3	ITYPE	Load Type Indicator =0 - Conservative Load =1 - Straight Acceleration Load =2 - Centripetal Acceleration Load =3 - Nonconservative Pressure Load
4	IPTR	Pointer to Additional Records =0 - No Additional Records >0 - Load Definition Continues in Record #IPTR
5	LCPTR	Pointer to Record with Loads for Next Loading Case
6	NNLC	Next Loading Case Number
7-18	F1(6)	Fraction of Element Length Between First End of Element and Beginning of Application of Distributed Load (in Component)
19-30	F2(6)	Fraction of Element Length Between Last End of Element and End of Application of Distributed Load
31-42	V1(6)	Distributed Load Components at Beginning of Application
43-54	V2(6)	Distributed Load Components at End of Application
55-66	VR(6)	Resultant Load Components

Data Set: ELD (For Lime Element) (Continued)

Location	Variable	Description
67-68	RES	Resultant Load Value
69-70	RESM	Resultant Moment Value
2	-NEL	Continuation Flag (Negative of Element Number)
2-6	IFREE(5)	Unused
7-66	VCON(6,5)	Distributed Load Components at Midpoints
67-70	FREE(2)	Unused

LDS

Type	;	Random Access
Status	;	Permanent, INTS

Data Size Parameters	;	IPRS = 160 (words)
		IBF = 10
		LRS = 16

Data Set Description. This data set consists of 'NLCT+1' groups of records, each group containing 'NGPT'+1 logical records. The first group (Number 0) is reserved for composite loading cases. The second group (Number 1) contains loading case 1, and so on.

The first logical record in each group is reserved for special purposes (e.g., weighting factors for composite loading cases, time values for transient response solutions, etc.)

No single physical record may contain more than one group of record. Each group must begin a new block.

It contains type of load group, time or frequency value in the first logical record in each group. From the second record, it contains loads and moments about 3-axes and their resultants.

Logical Record Contents (8 floating point)

Data Set: LDS (First Logical Record)

Location	Variable	Description
1	LDTYPE	Type of Load Group
		=0 - Simple Loading Case
		=1 - Time-varying Load Vector
		=2 - Inertia Loads (From Mode Shape Computation
		-- Current Frequency = VAL
		=3 - Fourier Series Component (SINE)
		=4 - Fourier Series Component (COSINE)
		=5 - Composite Loading Case
		=6 - Composite Loading Case (at Angle VAL)
2-3	VAL	Time (Sec) or Frequency (CPS) Value, or Fourier Term
4	MOD	Modification Flag
		=0 - Loads and Prescribed Displacements not Modified
		=1 - Loads Modified for this Loading Case
		=2 - Prescribed Displacements Modified
5-16	FREE(6)	Unused

Data Set: LDS (Subsequent Logical Records)

Location	Variable	Description
1-2	VX	Load in X-Direction
3-4	VY	Load in Y-Direction
5-6	VZ	Load in Z-Direction
7-8	MX	Moment About X-Axis
9-10	NY	Moment About Y-Axis
11-12	MZ	Moment About Z-Axis
13-14	RES	Load Resultant
15-16	RESM	Moment Resultant

TMP

Type	;	Random Access
Status	;	Permanent, INTS

Data Size Parameters	;	IPRS = 280 (words)
		IBF = 5
		LRS = 56

Data Set Description. This data set contains element temperature field information, two temperature values per node of each element. It has the same number of logical records as 'ELT' data set, and is organized equivalently. If element #I occupies logical records #N and #N+1 of 'ELT' data set, the elements nodal temperatures will be stored in the same manner.

Logical Record Contents (28 floating point)

Location	Variable	Description
1-56	VTMP(2,14)	Temperature Values of up to 14 Nodes (Same Order as the Element Corner Points in LCF Array of the Element Record). for Node 'I': VTMP(1,I) - Temp. of Node 'I', Top of Element VTMP(2,I) - Temp. of Node 'I', Bottom (Valid Only for 2-D Element)

NOTE. If the element has more than 14 nodes, the tempratures are continued in the next logical record(s).

TLD

Type	;	Random Access
Status	;	Permanent, INTS

Data Size Parameters	;	IPRS = 840 (words)
		IBF = 5
		LRS = 168

Data Set Description. This data set contains element thermal loads produced by the temperature field, six components per node. This data set has the same number of logical records as does the data set 'ELT', and is organized equivalently.

Logical Record Contents (84 floating point)

Location	Variable	Description
1-84	TLD(6,14)	Thermal Loads of up to 14 Nodes (Same Order as the Elemeni ͻorner Points LCP Array of the Element Record)

NUTE. If the element has more than 14 nodes, the thermal loads are continued in the next logical record(s).

LDC

Type ; Random Access

Status ; Permanent, INTS

Data Size Parameters ; IPRS = 160 (words)
IBF = 10
LRS = 16

Data Set Description. This data set contains the combination of the loads applied to the model and the thermal loads resulting from the applied temperatures. It is structured the same as is the data set 'LDS', with the exception that it has no reserved record group for composite loading cases.

Logical Record Contents (8 floating point)

Location	Variable	Description
1-2	VX	Comdined Load in X-Direction
3-4	VY	Combined Load in Y-Direction
5-6	VZ	Combined Load in Z-Direction
7-8	MX	Combined Moment About X-Axis
9-10	MY	Combined Moment About Y-Axis
11-12	MZ	Combined Moment About Z-Axis
13-14	RES	Combined Load Resultant
15-16	RESM	Combined Moment Resultant

NOTE. The first logical record contents of each group are the same as 'LDS'.

LDI

Type ; Random Access

Status ; Permanent, INTS

Data Size Parameters ; IPRS = 364 (words)
IBF = 1
LRS = 364

Data Set Description. This data set contains loads blocked by freedoms for solution, in groups of 'NUGRP' records. these are (NLCA+NLCSM-1)/NLCSM groups. The first group contains values for loading cases from 1 to NLCSM. The second group contains values for loading cases from NLCSM+1 to 2*NLCSM.

Logical Record Contents (4 integer + 180 floating point)

Location	Variable	Description
1	NR	Row and Column Position of this Submatrix
2	NC	in the 'LDI' Matrix
3	NF	Number of Unknowns in Group
4	NLC	Number of Loading Cases in This Submatrix
5-364	XLDI(18,10)	Loads for 'NLC' Loading Cases for all Unknowns contained in this Group (Column-Wise)

SDY

Type ; Random Access

Status ; Permanent, INTS

Data Size Parameters ; IPRS = 210 (words)
IBF = 5
LRS = 42

Data Set Description. This data set contains 'NUGRP' records of stiffness directory, each describing the submatrix distribution in one row of the global stiffness matrix.

Logical Record Contents (42 integer)

Location	Variable	Description
1	NFR	Number of Rows in Group (Superrow)
2	NFP	First Node Number with Freedoms in this Group
3	NLP	Last Node Number with Freedoms in this Group
4-21	LDP(18)	List Showing Rows with Prescribed Displacements LPD(I) = 0 - Displacement Not Prescribed LPD(I) = 1 - Displacement Prescribed
22	NS	Number of Submatrix Strings in the Row (Max. 9)
23	IFSPTR	Pointer to Stiffness Data Set Record Number of First Submatrix in the Row
24	IBAK	Pointer to the Earliest Preceding Row Which Interacts with the Current Row
25-42	LC(2,9)	List of Column Strings Where Non-zero Submatrix are Present. For String 'I': LC(1,I) - No. of First Column in String LC(2,I) - No. of Last Column in String

STF

Type	;	Random Access
Status	;	Permanent, INTS

Data Size Parameters	;	IPRS = 652 (words)
		IBF = 1
		LRS = 652

Data Set Description. This data set contains the stiffness matrix. Each logical record contains submatrix of the stiffness matrix.

Logical Record Contents (4 integer + 324 floating point)

Location	Variable	Description
1	NR	Row and Column Position of This Submatrix
2	NC	in the Supermatrix
3	NFR	Number of Rows in Submatrix
4	NFC	Number of Columns in Submatrix
5=652	SM(18,18)	Stiffness Submatrix, Stored Column-Wise. Only the First 'NFR' Rows and First 'NFC' Col. Have any Meaning

DNS

Type	;	Random Access
Status	;	Permanent, INTS

Data Size Parameters	;	IPRS = 160 (words)
		IBF = 10
		LRS = 16

Data Set Description. This data set contains nodal point deflection components and resultants. It also contains a total of 'NLCA' groups of records. Its structure identical to 'LDS' data set.

Logical Record Contents (8 floating points)

Data Set: DNS (first logical record)

Location	Variable	Description
1	IDENTYP	Deflection Type =0 - Simple Loading Case =1 - Transient Response or Other Time Varying Solution TIME = 'VAL" Sec. =2 - Mode Shape - FREQ. = 'VAL' C.P.S. =3 - Fourier Series Component (SINE) =4 - Fourier Series Component (COSINE) =5 - Composite Loading Case =6 - Composite Loading Case (at Angle 'VAL')
2-3	VAL	Time or Freq. Value, or Fourier Term

Data Set: DNS (first logical record) (Continued)

Location	Variable	Description
4	MOD	Modification Flag =0 - Deflections Not Modified =1 - Delfections Modified
5-16	FREE(6)	Unused

Data Set: DNS (subsequent logical records)

Location	Variable	Description
1-2	U	X-Displacement
3-4	V	Y-Displacement
5-6	W	Z-Displacement
7-8	THX	Rotation About X-Axis
9-10	THY	Rotation About Y-Axis
11-12	THZ	Rotation About Z-Axis
13-14	DIS	Resultant Displacement $(\sqrt{U^2 + V^2 + W^2})$
15-16	ROT	Resultant Rotation $(\sqrt{THX^2 + THY^2 + THZ^2})$

DNI

Type ; Random Access

Status ; Permanent, INTS

Data Size Parameters ; IPRS = 364 (words)
IBF = 1
LRS = 364

Data Set Description. This data set contains deflections blocked by freedoms for solution, in group of 'NUGRP' records. It is structured exactly same as 'LDI' data set.

Logical Record Contents (4 integer + 180 floating point)

Location	Variable	Description
1	NR	Row and Column Position of this Submatrix
2	NC	in the 'DNI' Matrix
3	NF	Number of Unknowns in Group
4	NLC	Number of Loading Cases in this Submatrix
5-364	XDIN(18,10)	Deflections for 'NLC' Loading Cases (Column-wise)

STR

Type	;	Random Access
Status	;	Permanent, INTS

Data Size Parameters	;	IPRS = 160 (words)
		IBF = 10
		LRS = 16

Data Set Description. This data set contains element stress and/or strain values, one per stress point per layer for each element, and one per stress point for each element. It is divided into major groups. Each major group of the data set contains one group of records for every stress point in each element. The group contains all stress, stress resultant and/or strain information for all layers of stress values at that stress point. The mode and problem class switches in 'PAR' data set detrmine which of these sets of data are actually stored in the data set. It contains a total of 'NSTRP' stress records for each loading case. The first logical record in each group is reserved for future use. The presence or absence of each of the following logical record types is determined by the values of the two status switches in 'PAR'. They are as follows:

<STRESS RESULTANTS> and <STRESSES>	;	Present if ISTES = 1
<STRAINS>	;	Present if ISTESN = 1
<TOTAL PLASTIC STRAINS>	;	Prsent if ISTESN = 1 and Either ISWMNL > 0 or ISWGNL > 0

Logical Record Contents (8 floating point)
Data Set: STR (Stress Resultant - 1 record)

Location	Variable	Description
1-12	RST(6)	Up to 6 Stress Resultant Components Per Stress Point for Each Element
13-16	FREE(2)	Unused

Data Set: STR (Stresses - 'NLAYR' records)

Location	Variable	Description
1-12	STR(6)	Up to 6 Stress Components Per Stress Point Per Layer for Each Element
13-16	FC(2)	Two Failure Cirterion (in Percent)

NOTE. The layers are ordered from the bottom to the top of the element.

Data Set: STR (Strains - 'NLAYR' records)

Location	Variable	Description
1-12	STN(6)	Up to 6 Strain Components Per Stress Point Per Layer for Each Element
13-16	FREE(2)	Unused

Data Set: STR (Total Plastic Strains - 'NLAYR' records)

Location	Variable	Description
1-12	STNP(6)	Up to 6 Plastic Strain Components Per Stress Point Per Layer for Each Element
13-16	FREE(2)	Unused

NOTE. The layers are ordered from the bottom to the top of the element.

RES

Type ; Random Access

Status ; Permanent, INTS

Data Size Parameters ; IPRS = 840 (words)
IBF = 5
LRS = 168

Data Set Description. This data set contains element residual forces RES = K*DNS. It has the same number of records as the data set 'ELT'. It is organized equivalently to the data set 'ELT'.

Logical Record Contents (84 floating point)

Location	Variable	Description
1-168	RES(6,14)	Residual Forces (Including Moments) of up to 14 Nodes. (Same Order as the Element Corner Points in 'LCP' of the Data Set 'ELT'.) If the Element has More Than 14 Nodes, the Residual Forces are Continued in the Next Record.

CFR

Type ; Random Access

Status ; Permanent, INTS

Data Size Parameters ;

Data Set Description. This data set contains saved contour values and failure criterion ranges from module 'RESULT'. It will contain either or both of the following records. It depends on the values of the parameters 'ISWRNG' and 'ISWCNT' in the seventh record of the data set 'PAR'.

Total Record Contents.

1) 'ISWRNG' = 1; NRNG - Number of Failure Criterion Ranges
RNG(3,10) - Saved Ranges:
RNG(1,I) - Character
RNG(2,I) - Min. F.C. Value
RNG(3,I) - Max. F.C. Value

2) 'ISWCNT' = 1; NCONTR - Number of Contour Values
VCONTR(20) - Contour Values

4.6.4 Dynamic Analysis Group

The following data sets are generated by GIFTS during the execution of dynamic analysis modules.

LDT

Type ; Random Access

Status ; Permanent, INTS

Data Size Parameters ; IPRS = 146 (words)
IBF = 1
LRS = 146

Data Set Description. This data set contains temporary load and mass and damping coefficient information for a transient response problem. It has a total of 'NUGRP' logical records blocked by freedoms.

Logical Record Contents (2 integer + 72 floating point)

Location	Variable	Description
1	NG	Freedom Group Number (Row of Supermatrix)
2	NF	Number of Freedoms in Group
3-38	BRT1(18)	Load Vector at Time T = DEL
38-74	BRT2(18)	Acceleration Vector at Time t = 0
75-110	BRT3(18)	Nodal Point Masses
111-146	BRT4(18)	Damping Coefficient

DNT

Type ; Random Access

Status ; Permanent, INTS

Data Size Parameters ; IPRS = 146 (words)
IBF = 1
LRS = 146

Data Set Description. This data set contains the time history of a transient response problem for the previous three time steps. It has a total of 'NUGRP' logical records blocked by freedoms.

Logical Record Contents (2 integer + 74 floating point)

Location	Variable	Description
1	NG	Freedom Group Number (Row of Supermatrix)
2	NF	Number of Freedoms in Group
3-38	DN4(18)	Empty - Will be Used for Deflection at T= TM + DEL
39-74	DN3(18)	Deflections at Time T = TM
75-110	DN2(18)	Deflections at Time T = TM - DEL
111-146	DN1(18)	Deflections at Time T = TM - 2*DEL

NOTE. This data set will contain the different time history of a transient response problem if the user runs the other transient response analysis modules 'NEW1' and 'NEWS'. Velocity and acceleration vectors are stored in DN2(18) and DN1(18) instead of deflection vectors (Newmark's method employed).

DNH

Type ; Random Access

Status ; Permanent, INTS

Data Size Parameters ; IPRS = 160 (words)
IBF = 10
LRS = 16

Data Set Description. This data set contains the deflection history generated by transient response and incremental problems. It is structured exactly the same as the data set 'DNS', except that it will contain one set of displacements for every time step. And it will not contain resultants. The first logical record at the beginning of each set of displacements (each time step) will contain the time.

Logical Record Contents (8 floating point)

Location	Variable	Description
1-2	U	X-Displacement
3-4	V	Y-Displacement
5-6	W	Z-Displacement
7-8	THX	Rotation About Z-Axis
9-10	THY	Rotation About Z-Axis
11-12	THZ	Rotation About Z-Axis
13-16	FREE(2)	Unused

UGC

Type ; Random Access

Status ; Permanent, INTS

Data Size Parameters ; IPRS = 364 (words)
IBF = 1
LRS = 364

Data Set Description. This data set contains the unit generalized coordinate vectors computed by the virbrational analysis modules (AUTOL, SAVEK, SUBS). The vectors are used as the basis for modal analysis. It is structured the same as the data set 'DNI' blocked by freedoms. There will be one vector for each mode shape.

Logical Record Contents (4 integer + 180 floating point)

Location	Variable	Description
1	NR	Row and Column Position of This Submatrix
2	NC	in the 'UGC' Supermatrix
3	NF	Number of Freedoms in Group
4	NGCGT	Number of Modes in this Group
5-365	VLD(18,10)	Normalized Mode Shapes for 'NGCGT' Modes

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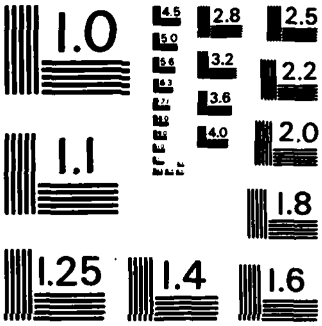

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SAV

Type ; Sequential Access

Status ; Permanent

Data Size Parameters ; Dependent on Problem Scale

Data Set Description. This data set contains the saved stiffness matrix. Only non-zero submatrices of the data set 'STF' are stored. The last record in the data set contains zeros for ISA, NR, NC, NFR, NFC, NFRC, NFCC and a dummy submatrix. It has a total of 'ISA+1' records.

Record Contents

Location	Variable	Description
1	ISA	Record No. in 'STF' from Which Submatrix was Stored
2	NR	Row and Column Numbers of the Suhmatrix
3	NC	in Stiffness Supermatrix
4	NFR	Numbers of Columns and Rows in
5	NFC	Submatrix
7	NFRC	Number of Non-zero Columns and Rows
8	NFCC	in Submatrix
9-?	SM(NFRC,NFCC)	Compacked Stiffness Submatrix

HST

Type ; Sequential Access

Status ; Permanent

Data Size Parameters ; 15 integer + 400 floating

Data Set Description. This data set contains all information pertaining to a transient response history. It can store up to 4 degrees of freedom.

Record Contents

Location	Variable	Description
1	NH	Number of History Points Stored
2	NDH	Number of Time Steps Per History Point
3	NSL	Number of Time Steps Remaining Before Next History Point is Stored
4-15	LISTF(3,4)	List of Point/Freedom Conbinations for Each Row: LISTF(1,I) - User Node Number LISTF(2,I) - System Node Number LISTF(3,I) - Freedom Number
10-800	HIST(100,4)	History Point Values, up to a Max. of 100 Per Freedom

NOTE. The arrays 'LISTF' and 'HIST' are stored column-wise.

DYN

Type	;	Sequential Access
Status	;	Permanent, Real
Data Size Parameters	;	Dependent on User Definition

Data Set Parameters. This data set contains the condensed stiffness, mass and damping matrices for use in the computation of the modes of vibration or the transient response using modal superposition.

Record Contents

CBK(NLCA,NLCA)	Condensed Stiffness Matrix
CM(NLCA,NLCA)	Condensed Mass Matrix
CC(NLCA,NLCA)	Condensed Damping Matrix

4.6.5 Substructural Analysis Group

The following data sets are generated by GIFTS during the execution of constrained substructure analysis modules. (DEFCS, REDCS, LOCAL)

INT

Type ; Random Access

Status ; Permanent, INTS

Data Size Parameters ; IPRS = 50 (words)
IBF = 10
LRS = 5

Data Set Description. This data set contains a series of records, each describing the order of interpolation (rigid, linear, cubic) and listing the master nodes of one interface (from which the displacements of the dependent nodes are computed).

Logical Record Contents (5 integer)

Location	Variable	Description
1	IORD	Order of Interpolation
2	NMP	Number of Master Points in Interface
3-5	L(3)	List of Master Points (Max. 3)

TDE

Type ; Random Access

Status ; Permanent, INTS

Data Size Parameters ; IPRS = 652 (words)
IBF = 1
LRS = 652

Data Set Description. This data set contains submatrices of the external-dependent deflection transformation matrix (TDE). It has a total of NEG*NDG logical records.

Logical Record Contents (4 integer + 324 floating point)

Location	Variable	Description
1	NR	Row and Column Number of this Submatrix
2	NC	in the TDE Supermatrix
3	NDF	Number of Rows in Submatrix
4	NEF	Number of Columns in Submatrix
5-652	TDE(18,18)	Submatrix - Only (NDF*DEF) Components Have Any Meaning

NOTE. For the submatrix relating dependent freedom group 'NDC' to external freedom group 'NEC', the record number 'NR' is computed from the relation: NR = NDG*(NEG-1) + NDC. As the entire matrix is stored, an indicator is stored with zero value for 'NDF' to flag out zero submatrices.

TIE

Type ; Random Access

Status ; Permanent, INTS

Data Size Parameters ; IPRS = 652 (words)
IBF = 1
LRS = 652

Data Set Description. This data set contains the transformation matrix by which internal node deflections are computed from external node deflections. It has a total of NIG*NEG logical records (where NIG is the number of internal freedom groups).

Logical Record contents (4 integer + 324 floating point)

Location	Variable	Description
1	NR	Row and Column Number of This
2	NC	Submatrix in the 'TIE' Supermatrix
3	NIF	Number of Rows in Submatrix
4	NEF	Number of Columns in Submatrix
5-652	TIE(18,18)	Submatrix

NOTE. 'NR' is computed from:

NR = NIG*(NEC-1) + NIC

The individual submatrices contain the zero indicators as TDE submatrices.

KEE

Type	;	Random Access
Status	;	Permanent, INTS

Data Size Parameters	;	IPRS = 652 (words)
		IBF = 1
		LRS = 652

Data Set Description. This data set contains all above-diagonal submatrices of the condensed stiffness matrix of a substructure. It has a total of (NEG*(NEG+1))/2+1 logical records, where NEG is the number of external freedom groups. The first logical record contains three coordinates of the substructure's external nodes, selected by module 'REDCS' to be used by module 'STIFF'. The record number N is counted from: N = ((NR-1)*((2*NEG+1) - (NR-1)))/2 + (NC-NR+2)

Logical Record Contents (4 integer + 324 floating point)

Location	Variable	Description
		1) The First Logical Record
1-3	NEP(3)	External Point Numbers
4-9	VC1(3)	Coordinates of the First Node
10-15	VC2(3)	Coordinates of the Second Node
16-21	VC3(3)	Coordinates of the Third Node
22-652	--	Unused
		2) The Subsequent Logical Records
1	NR	Row and Column Number of This Submatrix
2	NC	in the 'KEE' Supermatrix
3	NFR	Number of Rows in KEE Submatrix
4	NFC	Number of Columns in KEE submatrix
5-652	VKEE(18,18)	Submatrix

MEE

Type	;	Random Access
Status	;	Permanent, INTS

Data Size Parameters	;	IPRS = 652 (words)
		IBF = 1
		LRS = 652

Data Set Description. This data set contains all above-diagonal submatrices of the condensed mass matrix of a substructure. It has (NEG*NEG+1))/2 records, where 'NEG' is the number of external freedom groups. The record number N is counted from:
N = ((NR-1)*((2*NEG+1) - (NR-1))/2 + (NC-NR+1)

Logical Record Contents (4 integer + 324 floating point)

Location	Variable	Description
1	NR	Row and Column Number of this Submatrix
2	NC	in the 'MEE' Supermatrix
3	NFR	Number of Rows in this Submatrix
4	NFC	Number of Columns in this Submatrix
5-652	VMEE(18,18)	Submatrix

CEE

Type	;	Random Access
Status	;	Permanent, INTS

Data Size Parameters	;	IPRS = 652 (words)
		IBF = 1
		LRS = 652

Data Set Description. This data set contains all above-diagonal submatrices of the condensed damping coefficient matrix of a substructure. It has (NEG*(NEG+1))/2 logical records. The record number N is counted from:
N = ((NR-1)*((2*NEG+1) - (NR-1)))/2 + (NC-NR+1)
there are no zero indicators stored with the data set.

Logical Record Contents (4 integer + 324 floating point)

Location	Variable	Description
1	NR	Row and Column Number of This Submatrix
2	NC	in the 'CEE' Supermatrix
3	NFR	Number of Rows in this Submatrix
4	NFC	Number of Columns in this Submatrix
5-652	CEE(18,18)	Submatrix

CLD

Type ; Random Access

Status ; Permanent, INTS

Data Size Parameters ; IPRS = 364 (words)
IBF = 1
LRS = 364

Data Set Description. This data set contains the condensed load matrix for a substructure.

Logical Record Contents (4 integer + 180 floating point)

Location	Variable	Description
1	NR	Row and Column Number of This Submatrix
2	NC	in the 'CLD' Supermatrix
3	NIF	Number of Rows in this Submatrix
4	NLC	Number of Loading Cases in This Submatrix
5-364	CLD(18,10)	Condensed Load Submatrix for 'NLC' Loading Cases

CDN

Type ; Random Access

Status ; Permanent, INTS

Data Size Parameters ; IPRS = 364 (words)
IBF = 1
LRS = 364

Data Set Description. This data set contains internal nodal displacement components due to internal loading: ${K_{II}}^{-1}*R_I$

Logical Record Contents (4 integer + 180 floating point)

Location	Variable	Description
1	NR	Row and Column Number of This Submatrix
2	NC	in the 'CDN' Supermatrix
3	NIF	Number of Rows in this Submatrix
4	NLC	Number of Loading Cases in This Submatrix
5	CDN(18,10)	Condensed Deflection Submatrix for 'NLC' Loading Cases

TEM

Type ; Random Access

Status ; Permanent, INTS

Data Size Parameters ; IPRS = 652 (words)
IBF = 1
LRS = 652

Data Set Description. This data set contains all above-diagonal submatrices of the condensed temperature matrix of a substructure. It has (NEG*(NEG+1))/2+1 logical records. The first logical record contains three coordinates of the substructure's external nodes.

Logical Record Contents (4 integer + 324 floating point)

Location	Variable	Description
		1) First Logical Record
1-3	NEP(3)	External Node Numbers of the Three Nodes (Same as System Numbers)
4-9	VC1(3)	Coordinates of the First Node
10-15	VC2(3)	Coordinates of the Second Node
16-21	VC3(3)	Coordinates of the Third Node
22-652	--	Unused
- - - -	- - - -	- - - - - - - - - - - - - - - - - -
		2) Subsequent Logical Records
1	NR	Row and Column Number of This Submatrix
2	NC	in the 'TEM' Supermatrix
3	NFR	Number of Rows in This Submatrix
4	NFC	Number of Columns in This Submatrix
5-652	TEM(18,18)	Submatrix

4.6.6 Temporary Group

The following data sets are temporary in GIFTS. They exist only during the execution of the module and are deleted upon its successful termination. Some of them are replaced with the old data sets.

LDX

Type	;	Random Access
Status	;	Temporary, INTS

Data Size Parameters	;	IPRS = 160 (words)
		IBF = 10
		LRS = 16

Data Set Description. This data set is used for temporary storage of the records in 'LDS'. When 'NGPT' is greater than the default size number, the data set 'LDX' is generated with NGPT+1 logical records for each group. The old data set 'LDS' is deleted and replaced by the new data set 'LDX' with the name of 'LDS'.

Logical Record Contents. (8 floating point) The logical record contents are exactly the same as those of 'LDS'.

PTX

Type	;	Random Access
Status	;	Temporary, INTS

Data Size Parameters	;	IPRS = 440 (words)
		IBF = 10
		LRS = 44

Data Set Description. This data set is used for temporary storage of the records in 'PTS'. When it is necessary to enlarge the size of the data set, this data set is generated. The old data set 'PTS' is deleted and replaced by the new data set 'PTX' with the name of 'PTS'.

Logical Record Contents. (10 integer + 17 floating point) The logical record contents are exactly the same as those of 'PTS'.

SLX

Type ; Random Access

Status ; Temporary, INTS

Data Size Parameters ; IPRS = 180 (words)
IBF = 10
LRS = 18

Data Set Description. This data set is used for temporary storage of the records in 'SLI'. When it is necessary to enlarge the size of the data set, this data set is generated. The old data set 'SLI' is deleted and replaced by the new data set 'SLX' with the name of 'SLI'.

Logical Record Contents. (18 integer) The logical record contents are exactly the same as those of 'SLI'.

TMX

Type ; Random Access

Status ; Temporary, INTS

Data Size Parameters ; IPRS = 280 (words)
IBF = 5
LRS = 56

Data Set Description. This data set is used for temporary storage of the records in 'TMP'. When it is necessary to enlarge the number of logical records for each group, it is generated. The old data set 'TMP' is deleted and replaced by the new data set 'TMX' with the name of 'TMP'.

Logical Record Contents. (28 floating point) The logical record contents are exactly the same as those of 'TMP'.

OPØ

Type ; Random Access

Status ; Temporary, INTS

Data Size Parameters ; IPRS = 80 (words)
IBF = 40
LRS = 2

Data Set Description. This data set contains one record for each node, containing the directory information needed to rearrange the model's nodes from the best starting point checked by the module 'OPTIM'.

Logical Record Contents (2 integer)

Location	Variable	Description
1	LMN	Dual-purpose variable. |LMN| Contains the Old System Number of the Node in Record 'I'. The Sign of LMN is Used as a Flag That the Freedom Grouping for Analysis Should be Split at This Node (the Following Portion of the Model has no Physical Connection to the Preceeding Portion)
2	LMN	The Inverse of LMN. It is the New System Number at Which to Find Old Point 'I'

OP1

Type ; Random Access

Status ; Temporary, INTS

Data Size Parameters ; IPRS = 160 (words)
IBF = 40
LRS = 4

Data Set Description. This data set contains one logical record for each node, containing the freedom count and directory information needed to rearrange the nodes after optimization.

Logical Record Contents (4 integer)

Location	Variable	Description
1	NF	Number of Allowed Freedoms for Node 'I'
2	LMN	Old System Number of Node in Record 'I'
3	LNN	Current System Number of Node to Find Old Node 'I'
4	LFP	Scratch Area for Bandwidth Optimization

OP2

Type ; Random Access

Status ; Temporary, INTS

Data Size Parameters ; IPRS = 80 (words)
IBF = 40
LRS = 2

Data Set Description. This data set contains one record for each element, containing directory information to the corner points stored in 'OP3'.

Logical Record Contents (2 integer)

Location	Variable	Description
1	LEP	Pointer to First Node in 'OP3'
2	NCP	Number of Corner Points in 'OP3

OP3

Type ; Random Access

Status ; Temporary, INTS

Data Size Parameters ; IPRS = 40 (words)
IBF = 40
LRS = 1

Data Set Description. This data set contains one record for each node of each element. It is essentially just a long serial list of the corner node numbers, with pointers from each element to its first node in the list stored in 'OP2'.

Logical Record Contents (1 integer)

Location	Variable	Description
1	LCP	Corner Point Number

ELS

Type ; Random Access

Status ; Temporary, INTS

Data Size Parameters ; IPRS = 240 (words)
IBF = 10
LRS = 24

Data Set Description. This data set contains one record for each stress point for each element, describing the principal stresses at the stress point for the current level in the element's thickness (top, middle, bottom) and the current loading case.

Logical Record Contents (12 floating point)

Location	Variable	Description
1-6	SIGMA(3)	Principal Stresses - One for 1-D Elements - Two for 2-D Elements - Three for 3-D Elements
7-24	TRAN(3,3)	Rotational Transformation Matrix Relating the Principal Stress Coordinate System to the Global Coordinate System

4.7 DISCUSSION

In GIFTS database, all data pertaining to a problem are stored. Database processing is strictly controlled by GIFTS data management routines. Each data set is stored in a separate random or sequential access file. More than 15 data sets are generated during solution of a problem. This causes an increase in the overhead for manipulating the data files. If the data sets are properly categorized based on the characteristics of data, several data sets should be stored in a random or sequential file.

Drawback of the GIFTS database is that it is designed with reference to its particular solution scheme. Moreover, each data set requires its own data management routines (4 or 5). More than 200 data management routines are used in GIFTS library. Therefore we can conclude that GIFTS database does not meet all requirements stated in Section 2.3. We need a centralized database which allows interaction between GIFTS program and an optimization program. This should be taken into consideration in designing the new database.

5. DATA REQUIRED FOR FEM-BASED STRUCTURAL SYNTHESIS

5.1 INTRODUCTION

For the design of an efficient database, it is necessary to identify and classify the data to be used. The purpose of this chapter is to classify and describe the required data for FEM-based structural analysis and design optimization. Based on the characteristics of data, they can be categorized as follows:

(1) problem definition data

(2) system idealization data

(3) response analysis data

(4) optimization problem formulation data

(5) design sensitivity analysis data

(6) design improvement data

(7) graphic display data

In the subsequent sections, details of data classified above are listed. The capabilities considered are linear, nonlinear, static and dynamic analysis. Acceleration and/or temperature loads may be specified. Substructures may be used. Design optimization with these capabilities is considered.

5.2 DATA FOR PROBLEM DEFINITION

5.2.1 Overall Control Information

a) title of the problem
b) indicator for restarting job
c) indicator for job characteristics
- data check only
- analysis
- analysis and design optimization

d) indicator for unit selection
e) indicator for structural damage condition
f) indicator for database version
g) indicator for pre- and post-processor
h) indicator for graphic display
i) effective stiffness reformation time step
j) number of displacement constraint data for structural analysis
k) indicator for model generation status

5.2.2 System Modelling Information

a) total number of substructures
b) total number of element types
c) number of elements for each element type
d) total number of nodes
e) total number of material groups
f) number of damage conditions
g) number of active loading cases
h) indicator for type of BC/IC
i) total number of solution time steps
j) solution time interval
k) total number of master degrees of freedom

5.2.3 Parameters for Analysis Control

a) index for static/dynamic analysis
b) index for linear/nonlinear analysis
c) index for eigenproblems (vibration/buckling)
d) index for transient response analysis
e) index for eigensolution type
f) index for nonlinear analysis type
g) index for mass matrix type
h) index for eqilibrium iteration method
i) indices for convergence criteria
j) maximun number of equilibrium iterations
h) index for damping matrix type

5.2.4 Control Information for Design Optimization

a) index for optimization problem (unconstrained/constrained)
b) index for characteristic of cost function
c) index for optimization algorithm selection
d) index for design sensitivity analysis methods
(direct differentiation method/adjoint variable method)
e) index for type of constraints
f) data for convergence check (exact/inexact)
g) estimated number of local maximum points for each time-dependent constraint
h) constraint tolerance for active constraint
i) parameter for effective local maximum point
j) control parameters for selected algorithm
k) index for design-fixed substructure

5.2.5 Parameters for Output and Graphic Display Control

a) indices for output options
b) indices for graphic display options

5.2.6 Other Information

a) indicator for printout
b) measure of computation time

5.3 DATA FOR SYSTEM IDEALIZATION

5.3.1 Structure/Substructure Data

a) number of substructure
b) number of nodes in a master structure
c) number of nodes in a substructure (boundary/internal)
d) master node numbers
e) number of reused substructures
f) DOF information of a structure/substructure
g) element type indicator in a structure/substructure
h) number of elements in a strucure/substructure
i) number of mid-surface vector sets
j) damage information of a structure/substructure

5.3.2 Node Related Data

a) node numbers
b) node status (substructural boundary/internal)
c) nodal coordinates
d) nodal skew coordinate system
e) nodal mid-surface vector set number
f) nodal initial temperature
g) nodal reference coordinate system
h) DOF information
i) nodal non-structural masses
j) nodal damping coefficients
k) nodal loads
l) nodal temperature
m) nodal IC/BC information
n) nodal prescribed displacement information
o) number of prescribed nodal points
p) equation number for global structure
q) equation number for each substructure
r) link between master and substructure node number

5.3.3 Element Related Data

a) element numbers
b) element type
c) element connectivity information
d) number of nodes for each element type
e) material group numbers
f) material interpolation factors
g) numerical integration order
h) element damage information

i) element nonlinearity indictor
j) initial stress/strain information
k) number of layers
l) number of stress points per layer
m) thickness or cross-sectional shape code
n) thickness interpolation factors
o) parameters for principal plane or fiber direction
p) element load type indicator
q) elememt properties

5.3.4 Material Properties

a) material code number
b) material model number
c) number of constants for each material model
d) Young's modulus (E11,E22,E33)
e) Poisson's ratio (v12,v23,v31,v21,v13,v32)
f) shear moduli (G12,G23,G31)
g) yield criteria
h) material density
i) material interpolation type
j) linear thermal expansion coefficients (ALPHA1,ALPHA2,ALPHA3)
k) temperature table
l) strain hardening modulus
m) stress hardening parameters
n) index for composite/noncomposite material
o) number of given temperatures
p) uniaxial/biaxial/triaxial tensile/compressive ultimate stress/strain
q) shear stress limits
r) loading shear modulus
s) volume strain
t) loading/unloading bulk modulus
u) shear factor (for thick plate and shell elements)
v) normal/shear stiffness reduction factors
w) creep law number and associated constants

5.3.5 Loading Data

a) loading case number
b) load type (conservative/nonconservative)
c) number of concentrated loads
d) number of distributed loads
e) number of inertia loads
f) number of time dependent loads
g) number of load/time increments
h) concentrated load information
g) pressure information
i) thermal load information
j) inertia force information
k) time dependent load information
l) loading function multipliers
m) pressure multipliers

n) inertia force multipliers
o) reused substructure loads
p) arrival time for applied loads

5.3.6 Eigenproblem Data

a) number of frequencies and mode shapes
b) dimension of subspace
c) flag for suppressing zero frequencies
d) subspace iteration frequencies interval
e) maximum number of subspace iterations
f) flag for Sturm sequence check
g) shifting factor for subspace iteration
h) load pattern for buckling analysis

5.3.7 Other Information

a) damage reduction information
b) mid-surface normal information
c) modal damping factors

5.4 DATA FOR RESPONSE ANALYSIS

5.4.1 Element Level Data

a) linear element stiffness matrix
b) nonlinear element stiffness matrix
c) element mass matrix (lumped/consistent)
d) element load vectors

5.4.2 Structure Level Data

a) substructure stiffness matices (boundary,internal,internal-boundary)
b) substructure mass matrices (boundary,internal,internal-boundary)
c) substructure damping matrices (boundary,internal,internal-boundary)
d) condensed substructure stiffness matrices
e) condensed substructure mass matrices
f) condensed substructure damping matirces
g) assembled linear stiffness matix
h) assembled mass matrix
i) assembled damping matrix
j) effective substructure stiffness matrices
k) effective linear stiffness matrix
l) condensed stiffness matrix for modal anaysis
m) condensed mass matrix for modal analysis
n) condensed damping matrix for modal analysis
o) substructure load vector for each time step
p) load vector for each time step
q) effective substructure load vector for each time step
r) effective load vector for each time step

s) decomposed effective substructure stiffness matrices
t) decomposed effective linear stiffness matrix
u) assembled nonlinear stiffness matrix
v) final tangential stiffness matrix for each load step
w) final tangential effective stiffness matrix for each load step

5.4.3 Response Data

a) nodal displacements
b) nodal velocities
c) nodal accelerations
d) element stresses/stress resultants
e) element strains/strain resultants
f) element forces/force resultants
g) system buckling loads and mode shapes
h) natural freqencies and mode shapes

5.5 DATA FOR OPTIMIZATION PROBLEM FORMULATION

5.5.1 Data for Cost Function Formulation

a) total number of design variable groups
b) number of design variables for each group
c) lower/upper bounds on design variables
d) cost function factor for each material code
e) weighting factors for each type of cost function
f) user supplied cost function expression

5.5.2 Data for Constraints Formulation

a) total number of constraints (excluding explicit bounds on design variables)
b) number of stress constraints (integral type/point-wise)
c) number of displacemnet constraints (integral type/point-wise)
d) number of freqeuncy constraints
e) displacement constraint code number for each node
f) displacement limits for each displacement constraint code number
g) stress limits for each material code number
h) freqency limits for each freqeuncy code number
i) user supplied constraint expressions
j) allowable stresses for beam and truss element
k) supporting length for beam element
l) number and locations of effective local maximum points for each time-dependent constraint

5.5.3 Other Information

a) augmented Lagrangian expression for multiplier methods
b) Lagrange multipliers corresponding to active constraints
c) penalty parameters corresponding to active constraints
d) initial design

5.6 DATA FOR DESIGN SENSITIVITY ANALYSIS

5.6.1 Preliminary Information

a) derivative of cost function w.r.t design variables
b) derivatives of active constraints w.r.t design variables
c) derivatives of active constraints w.r.t state variables
d) derivative of augmented Lagrangian w.r.t design variables
e) derivative of augmented Lagrangian w.r.t state variables at
f) derivative of element stiffness matrix w.r.t design variables
g) derivative of nonlinear element stiffness matrix w.r.t state variables
h) derivative of element mass matrix w.r.t design varibles
i) derivative of nonlinear element mass matrix w.r.t state variables
j) derivative of damping matrix w.r.t design variables
k) derivative of force vector w.r.t design variables
l) derivative of internal force vector w.r.t design variables
m) for each substructure
n) derivative of boundary force vector w.r.t design variables
o) for each substructure
p) derivative of active constraints w.r.t internal state variables for each substructure
q) derivative of active constraints w.r.t boundary state variables for each substructure
r) total derivative of state variables w.r.t design variables for direct differentiation method
s) adjoint variable vector for gradient of cost function
t) adjoint varaible vectors for gradient of active constraints (*internal/boundary for substructure*)
u) adjoint variable vector for gradient of augmented Lagrangian
v) derivative of element stress-displacement matrix w.r.t design variables
w) derivative of allowable stresses w.r.t design variables
x) derivative of gemetric stiffness matrix w.r.t. design variables
y) derivative of nonlinear element strain-displacement matrices w.r.t. state variables
z) derivative of element constitutive matrices w.r.t state variables

5.6.2 Gradient Information

a) gradient of cost function
b) gradient of augmented Lagrangian
c) gradient of integral-type displacement constraints
d) gradient of point-wise displacement constraints
e) gradient of integral-type stress constraints
f) gradient of point-wise stress constraints
g) gradient of frequency constraints
h) gradient of buckling constraints

5.7 DATA FOR DESIGN IMPROVEMENT

a) upper/lower bounds of cost function
b) design change and improved design vectors
c) history of design variables

d) history of cost function
e) history of constraints
f) history of augmented Lagrangian
g) data for Hessian update

5.8 DATA FOR GRAPHIC DISPLAY

a) system geometry
b) element geometry

6. DESIGN OF PROPOSED DATABASE

6.1 INTRODUCTION

Based on database design procedures, collected information, and analysis of existing databases, a new design of databases for structural analysis and design optimization is proposed in this chapter. In designing the database, guidelines for information collection and general requirements for the database are followed.

In Section 6.2, flow of data for structural analysis and design optimization is described. Based on the data flow in structural analysis and optimization, data are catagorized into several groups according to their usage. A list of data sets are given in Section 6.3. Section 6.4 contains details of each data set. Structure of database is summarized in Section 6.5

The following notations are used in this chapter:

b - vector of design variable
B - element stress-displacement matrix; $\sigma = Bz$
C - daming matrix
CHAR - character variable
C_{mx}, C_{my} - Coefficient applied to bending term in interaction formula and dependent upon column curvature caused by applied moment (refer to AISC Steel Construction Manual)
$C_x, C_y, C_z, C_{xx}, C_{yy}, C_{zz}$ - nodal dampers in x, y, z directions (*translation and rotation*)
C^* - effective force gradient matrix (refer to Haug & Arora (1979));

$$C^* = C_1 + Q^T C_2$$

C_1 - part of effective force gradient matrix
C_2 - part of effective force gradient matrix
D - constitutive matrix
dof - degree of freedom
DMAT - Real Matrix
D.V. - design variables
$d(\cdot)/dz, d(\cdot)/db$ - partial derivative of $(\cdot)$ w.r.t. state variable, design variable, respectively
E - Young's modulus
F_e - element nodal force vector
F_{bx}, F_{by} - allowable compressive bending stress in x-, and y-direction, respectively (refer to AISC Steel Construction Manual)
F_{ex}, F_{ey} - Euler stress divided by factor of safety (refer to AISC Steel Construction Manual)
F_s - Allowable shear stress
I, or INT - integer variable
IVEC - integer vector
K_g - element geometric stiffness
K_s - linear element stiffness matrix
K_x, K_y - effective length factors (refer to AISC Steel Construction Manual)

l_x, l_y - unbraced length in x and y direction respectively (refer to AISC Steel Construction Manual)

M - mass matrix

M_c - element consistent mass matrix

M_d - element lumped/diagonal mass matrix

$M_x, M_y, M_z, M_{xx}, M_{yy}, M_{zz}$ - nodal masses in x, y, z directrion (translation and rotation)

M - Poison's ratio

R^{μ}or REAL - real

RVEC - real vector

RX,RY,RZ - rotatial dof in x, y, and z direction

T - time parameter

T_j - a local maximum line points for a constraint function

y - eigenvector

z - vector of state variables

σ - element stress vector

λ - adjoint matrix$^{()}$

λ_I, λ_B - adjoint matrices$^{()}$ associated with internal dof and effective boundary dof of substructure.

⋮ continuation

6.2 DATA FLOW IN STRUCTURE ANALYSIS AND DESIGN SENSITIVITY/OPTIMIZATION

6.2.1 Processing Steps in Structural Analysis

The following are the steps for linear/nonlinear/static/dynamic analysis.

1) structural idealization

2) generate linear element stiffness matrices corresponding to linear elements.

3) generate substructure stiffness matrices corresponding to boundary, internal, and internal-boundary. (usually linear elements are used in substructures).

4) generate element mass matrices

5) assemble substructure linear stiffness matrices

6) decompose substructural internal and boundary stiffness matrices

7) generate condensed substructure stiffness matrices

8) assemble linear stiffness matrix

9) assemble substructure mass matrices

10) condense substructure mass matrices

11) assemble mass matrix

12) form substructre damping matrices

13) condense substructure damping matrices

14) form damping matrix

15) form effective linear stiffness

16) calculate load vector for each time step and load case

17) impose boundary conditions

18) decompose effective linear stiffness in case of linear analysis

19) find linear and nonlinear part of element stiffness corresponding to nonlinear elements

20) assemble linear stiffness matrix correponding to nonlinear elements

21) assemble nonlinear stiffness matrix correponding to nonlinear elements

22) generate tangential stiffness matrix for each solution time step and load case

23) form tangential effective stiffness matrix for each solution time step and load case

24) compute frequencies and buckling load factor

25) compute mode shape(s) associated to frequencies and buckling load factor

26) form effective load vector for each time step

27) solve for displacement (or incremental displacement) for each solution time step and load case

28) iterate for equilibrium (generate updated stiffness matrix)

29) calculate displacement, velocity and acceleration matrices

30) calculate element strains, stresses, and forces for each time step and load case

31) calculate internal displacements for each substructure, time step and load case

32) calculate internal velocities and accelerations for each substructure, time step and load case

33) calculate element strains, stresses, and forces matrices for each substructure, time step and load case

The following table describes the flow of data in structural analysis.

Table 6.2.1 Data Flow in Structural Analysis

No.	Data generated/required	Data used
1	overall control information see Section 5.2.1	none
2	system modeling information see Section 5.2.2	none
3	parameters for analysis control see Section 5.2.3	none
4	parameters for output and graphics display control see Section 5.2.5	none
5	other information see Section 5.2.6	none
6	substructure numbers	none
7	number of nodes in a master structure	none
8	number of nodes in a substructure (boundary/internal)	none
9	master node numbers	none
10	number of reused-substructures	none
11	equation number information of structure/substructure	16
12	element type indicator in a structure/substructure	none
13	number of elements in a strucure/substructure	none
14	number of mid-surface vector sets	none
15	damage information of a structure/substructure	none
16	node-related data see Section 5.3.2	none
17	element -related data see Section 5.3.3	none
17.1	contribution of equation number to hypermatrix	none
18	material properties see Section 5.3.4	none
19	loading data see Section 5.3.5	none
20	no. of frequencies and mode shapes	none

Table 6.2.1 Data Flow in Structural Analysis (continued)

No.	Data generated/required	Data used
21	load pattern for buckling analysis	none
22	damage reduction information	none
23	mid surface normal vector information	none
24	modal damping factors	none
25	linear element stiffness matrices associated with linear elements	14,16,17, 18,23
26	transformation matrix(structure/substructure)	16,17
27	assembled substructure stiffness matrices	6,10,13, 15,16,17, 22,25,26
28	condensed substructures stiffness matrices	11,8,27
29	*element mass matrices*	16,17,18
30	assembled substructure mass matrices	6,10,13, 15,16,17, 22,26,29
31	condensed mass matrices (e.g., Guyan Reduction)	11,30
32	substructure damping matrices	16
33	condensed damping matrices	11,32
34	effective substructure linear stiffness matrices	6,27,30, 32
34.1	decomposed substructure effective linear stiffness matrices(internal and boundary)	34
35	assembled linear stiffness matrix	6,9,10, 11,17,25 28
36	assembled mass matrix	6,9,10 11,29,31

Table 6.2.1 Data Flow in Structural Analysis (continued)

No.	Data generated/required	Data used
37	damping matrix	6,9,10 16,24,33
38	effective linear stiffness matrix	35,36,37
38.1	decomposed linear stiffness matrices	38
39	load vectors for each solution time step, and load case for each substructure	6,11,15 16,18,19
40	equivalent load vector for each solution time step and load case for each su'bstructure	11,27,39
		used
40.1	effective substructural load	11,39,54, 55,56,63 64,65
41	load vector for each solution time step and load case for global structure	40, 6,11
42	effective load vector for each time step and load case for global structure	11,36,37 41,54, 55,56
43	decomposed linear effective stiffness matrix	38
44	linear and nonlinear element stiffness matrices associated to nonlinear elements	14,16,17 18,23,54
45	assembled linear stiffness matrices associated to nonlinear elements	9,16,17 44
46	assembled nonlinear stiffness matrices associated to nonlinear elements for each solution time step and load case	9,16,17 44
47	tangential stiffness matrix to nonlinear elements for each solution time step	45,46 44
48	tangential effective stiffness matrix	36,37,47
49	decomposed tangential effective stiffness matrix	48

Table 6.2.1 Data Flow in Structural Analysis (continued)

No.	Data generated/required	Data used
50	frequencies and mode shapes	20,31 or 36,35 or 46
51	modal stiffness matrix	35,50
52	modal mass matrix	36,50
53	buckling load factor and buckling mode shape	21, 44 45
54	displacement(or incremental displacement) for each solution time step and each load case	41,42 or 49
55	accelerations	54,56
56	velocities	54,55
57	displacements from modal superpositon	50,51,52
58	velocities from modal superposition	50,57
59	accelerations from modal superposition	50,57 or 58
60	element strains for each solution time step and load case	16,17,54 or 57
61	element stresses for each solution time step and load case	18,54 or 60
62	element forces for each solution time step and load case	25 or 44, 54 or 57
63	internal displacement for each substructure, solution time step and load case	6,11,19, 34,54 or 57
64	internal acceleration for each substructure, solution time step and load case	63,65
65	internal velocity for each substructure, solution time step and load case	63,64

Table 6.2.1 Data Flow in Structural Analysis (continued)

No.	Data generated/required	Data used
66	element strains for each solution time step and load case of the substructure	16,17,54 or 57,63
67	element stresses for each solution time step and load case of the substructure	18,54,64 66
68	element forces for each solution time step and load case of the substructure	25 or 44, 54 ,64

6.2.2 Processing steps in Design Optimization

The following are the typical steps for design optimization:

1) cost function formulation

2) constraint functions formulation
   - displacement constraints
   - stress constraints
   - frequency constraints
   - buckling constraint
   - user supplied constraints

3) check the constraints
   - evaluate the constraint functions
   - find the effective local maximum points (time measure) for each constraint in dynamic case

4) form the active constraint set

5) compute gradients of cost and constraint functions
   - design derivatives of element property matrices
   - response (state) derivatives of element property matrices
   - second order derivatives if required

6) compute design change
   - compute the design direction
   - determine the step size if required

7) find new design varibles

8) check the convergence criteria

The following table describes the flow of data in design optimization.

Table 6.2.2 Data Flow in Design Optimization

No.	Data generated/required	Data used
101	control information for design optimization (see Section 5.2.4)	none
102	design variablc data(no. of groups, no. of design variable for each group, bounds on design variable, and initial design variable)	none
103	cost function factor and weighting factor	
104	data for constraint formulation(see section 5.5.2)	none
105	data for displacement constraint check	16,54 or 57,63,104
106	data for stress constraint check	17,61 or 104
107	data for frequency constraint check	50,104
108	*data for buckling constraint check*	53,104
109	data for user supplied constraint check	105,106, 107,108
110	constraint function status (See IDESIGN program written by J.S.ARORA)	none
111	Lagrangian multipliers and penalty parameters for multiplier methods	104,105, 106,107, 108,109
112	data for augmented Lagrangian formulation	102,103, 104,105, 106,107, 108,109 110,111
113	derivative of cost function w.r.t design variables	102,103
114	derivatives of constraint functions w.r.t design variables	102,104, 110
115	derivatives of constraint functions w.r.t state variables	104

Table 6.2.2 Data Flow in Design Optimization (continued)

No.	Data generated/required	Data used
116	derivatives of element constitutive matrices w.r.t state variables	18,61
117	derivatives of linear and nonlinear element element stiffness matrices w.r.t design variables	14,16,17, 18,23
118	derivatives of nonlinear part of element stiffness matrices w.r.t state variables	14,16,17, 18,23,54
119	derivatives of element stresses w.r.t design variables	14,16,17, 18,23
120	derivatives of nonlinear element strain-displacement transformation matrices w.r.t state variables	14,16,17, 18,23,54 or 57,63
121	derivatives of element stresses w.r.t state variables	18,116,120
122	derivative of element mass matrices w.r.t design variables	16,17,18
123	derivatives of element mass matrices w.r.t state variables	16,17,18 54
124	derivative of damping matrix w.r.t design variables	6,9,10, 16,24,33
125	derivative of damping matrix w.r.t state variables	6,9,10, 16,24,33
126	derivatives of element force vector w.r.t design variables	6,11,15, 16,18,19
127	derivatives of element force vector w.r.t state variables	6,11,15, 16,18,19
128	derivative of element residual forces w.r.t design variables	117,122, 124,126
129	total derivative of state variables w.r.t design variables	116,118, 121,122, 123,124, 125,126

Table 6.2.2 Data Flow in Design Optimization (continued)

No.	Data generated/required	Data used
130	derivative of augmented Lagrangian w.r.t design variables	111,112, 113,114
131	derivatives of augmented Lagrangian w.r.t state variables	111,112, 115
132	adjoint variable vector for gradient of augmented Lagrangian	35,36,37, 113,130, 131
133	adjoint variable vectors for gradient of constraint functions	35,36,37, 115
134	derivatives of internal/boundary force vectors w.r.t design variables for each substructure	6,11,15,16 18,19,54 or 57,63, 17,102
135	derivatives of constraint functions w.r.t internal/ boundary state variables for each substructure	104,120
136	derivatives of equivalent internal force vectors w.r.t design variables for each substructure	6,54,63, 117,134
137	derivatives of effective boundary force vectors w.r.t design variables for each substructure	6,27,34.1 54,63,117 134,136
138	internal/boundary adjoint variable vectors for each substructure	6,28,34.1 27,115 135,
139	derivative of allowable stresses w.r.t design variables	16,17,18 102
140	total derivative of frequency w.r.t design variables	50,117 122
140.1	derivative of eigenvector w.r.t design variables	50,117, 122
141	derivative of element geometric stiffness matrix w.r.t design variables	14,16,17 102,121
142	total derivative of buckling load factor w.r.t design variables	53,117, 141

Table 6.2.2 Data Flow in Design Optimization (continued)

No.	Data generated/required	Data used
143	design sensitivity vector for cost function	113
144	design sensitivity vector for augmented Lagrangian	128,129, 130,131, 132
145	design sensitivity matrix for constraint functions	104,114 136,137 133,140 142
146	upper/lower bounds of cost function	none
147	design change and improved design vectors	102,110 144,145 146
148	history of design variables	147
149	history of cost function	none
150	history of constraints function violation	104,110
151	history of augmented Lagrangian	111,112 148
152	Hessian matrices of augmented Lagrangian	148,151 147

6.3 LIST OF DATA SETS

In this section, data collected in Chapter 5 are classified into several groups based on their characteristics. Classification of data is an important step in designing an efficient database. In each data group, data sets are defined. Brief description of each data set is also presented in this section. The summary of data sets can be conveniently used as a dictionary of database.

The data set names are arranged in an alphabetical order.

Naming convention for data set is -

A : Analysis group

C : Control information

D : Design problem formulation

I : Improved design

S : Sensitivity analysis and design optimization

AAGLMT : Assembled load matrix (global) for linear statics

AALBMT : Substructure load matrix (boundary)

AASIDN : Acceleration vector (global) for dynamics/nonlinear

ABCIIC : Bounadry condition and initial condition information

ABUCEL : Buckling load factor and mode shape

ACLDMT : Condensed load matrix for linear dynamics/nonlinear statics

ACODCM : Node-damping and mass matrix

ACOMPR : Composite-element properties (layered)

ACORDC : Node-coordinate for master structure

ACORDS : Node-coordinate for subsrtucture(s)

ACSDMT : Condensed substructure damping matrix

ACSSMT : Condensed substructure mass matrix

ADESMT : Decomposed effective linear stiffness matrix (global-dynamics)

ADFTES : Decomposed final tangential effective stiffness matrix

ADFTGS : Decomposed final tangential global stiffness matrix

ADGIDN : Displacement matrix (global) for linear/nonlinear dynamics

ADISPLG: Displacement matrix (global)

ADLSMT : Decomposed linear stiffness matrix (global)

ADSIDN : Displacement matrix (internal) for dynamics

ADSSMT : Decomposed effective substructure stiffness matrix

ADYNLD : Dynamic load definition

AEGVEC : Eigenvalues and eigenvectors

AELCON : Element-connectivity

AELDMT : Effective substructure load matrix for linear dynamics

AELGNI : Element general information

AELHYP : Equation numbers contributing to a hypermatrix

AELLOD : Element-load data for master structure

AELMAS : Element-mass matrix (lumped/diagonal)

AELMAT : Element-stiffness matrix (linear)

AELMSC : Element-mass matrix (consistent)

AELPRO : Element-properties

AELSMT : Effective linear stiffness matrix (global-dynamics)

AELTRF : Element-transformation matrix

AESSMT : Effective substructure stiffness matrix (dynamics)

AFOREL : Element nodal force vector

AFTESM : Final tangential effective stiffness matrix

AFTGSM : Final tangential global stiffness matrix

AGELMT : Global effective load matrix for linear/nonlinear dynamics

AGESMT : Generalized structural matrices for modal analysis

AGLDMT : Global load matrix for linear/nonlinear dynamics

AINLOD : Inertia node-load

AISREL : Initial strain vector (element)

AISTEL : Initial stress vector (element)

AMASHY	Assembled substructure mass matrices (internal)
AMATPR	Related linear material properties
AMIDS	Mid-surface normal vector information
ANODDF	Node-dof global structure
ANODLD	Equivalent node-load data for the master structure
ANODTM	Node-temperature
ANONMT1	Nonlinear material type 1
ANSTMT	Assembled nonlinear stiffness matrix
ASABDN	Substructure acceleration vector (boundary)
ASAIDN	Substructure acceleration vector (internal)
ASCLMT	Condensed load matrix (substructure) for linear statics
ASDISB	Substructure displacement matrix (boundary)
ASDISI	Substructure displacement matrix (internal)
ASDMAT	Substructure damping matrix (internal)
ASDMTB	Substructure damping matrix (boundary)
ASELLOD	Element-load data for substructure(s)
ASELMS	Substructure element-mass matrix (lumped/diagonal)
ASEMMC	Substructure element-mass matrix (consistent)
ASESMT	Substructure element-stiffness matrix (linear)
ASETRM	Substructure element-transformation matrix
ASFOEL	Substructure element nodal force vector
ASKEW	Skew coordinate system defintion
ASLDMT	Assembled damping matrix (global)
ASLIMT	Substructure load matrix (internal)
ASLMMT	Assembled mass matrix (global)
ASLOMB	Substructure load matrix (boundary) for linear statics
ASLOMI	Substructure load matrix (internal) for linear statics
ASLSMT	Assembled linear stiffness matrix (global)
ASMBON	Assembled substructure mass matrices (boundary)
ASMINB	Assembled substructure mass matrices (internal-boundary)
ASNOLD	Equivalent node-load data for substructure(s)
ASSBBN	Assembled substructure stiffness matrix (boundary)
ASSBIB	Assembled substructure stiffness matrix (internal-boundary)
ASSBIN	Assembled substructure stiffness matrix (internal)
ASSTAL	Substructure strain vector (element)
ASSTEL	Substructure stress vector (element)
ASTNEL	Element stiffness matrix (nonlinear)
ASTRAL	Strain vector (element)
ASTREL	Stress vector (element)
ASUBDF	Node-dof substructure(s)
ASUBGI	Substructural genreal information
ASVIDN	Substructure velocity vector (internal)
AVELDN	Velocity vector (global)
CDSIIF	Design optimization integer control information
CDSRIF	Design optimization real control information
CINTCL	Integer control information
CLGPNA	Lagrange multipliers and penalty parameters
CREAL	Real control information
CTITLE	Title of the problem
DACNIF	Constraint information
DALWST	Element allowable stresses
DDSPLT	Displacement limits
DFRQLT	Frequency limits
ICNHIS	Constraint violation history
IDGNVB	Design variables

IDSHIS : Design history
IDVGIF : Design variable group information
IDVHIS : Design variable history
IHISTA : History of augmented lagrangian
ISDGIF : Substructure design variable group information
SADJAL : Adjoint variables for augmented lagrangian gradient
SADJBB : Substructure-lamdab matrix (λB)
SADJII : Substructure-lamdai matrix (λI)
SADJNB : Lamdab matrix (adjoint variables for global dof) (λB)
SCNSGD : Constraint-gradient
SCSTGD : Cost-gradient
SDALBZ : Response derivatives of augmented lagrangian
SDALDB : Augmented lagrangian gradient
SDAWDB : Differential-allowable-stress
SDCBDZ : Substructure-boundary-constraint-gradient
SDCEDB : Differential-element-damping matrix (dC/db)
SDCIDZ : Substructure-internal-constraint gradient
SDDCDZ : Differential-constitutive matrix (nonlinear material)
SDEGDB : Differential-element-stress matrix
SDEGDZ : Differential-element-stress matrix ($d\sigma/dz$)
SDFBDB : Subatructure-effective-boundary-force gradient (C_1 - matrix)
SDFEDB : Element-force gradient (dF_e/db)
SDFEDZ : Element-force gradient (dF_e/dz)
SDGVDB : Differential-eigenvector matrix
SDKGDB : Differential-element-geometric stiffness matrix (dK_g/db)
SDKGDZ : Differential-element-geometric stiffness matrix (dK_g/dz)
SDKKDB : Substructure-differential-element-stiffness matrix (dK_s/db)
SDKSDB : Differential-element-stiffness matrix (dK_s/db)
SDKSDZ : Differential-element-stiffness matrix (dK_s/dz)
SDMCDB : Differential-element-mass matrix (dM_c/db)
SDMCDZ : Differential-element-mass matrix (dM_c/dz)
SDMDDB : Differential-element-mass matrix (dM_d/db)
SDMDDZ : Differential-element-mass matrix (dM_d/dz)
SDSBDZ : Differential-element-stress-displacement matrix (dB/dz)
SDSCDB : Substructure-differential-element-mass matrix (dM_c/db)
SDSDDB : Substructure-differential-element-mass matrix (dM_d/db)
SDSFDB : Substructure-element-force gradient (dF_e/db)
SDSGDB : Substructure-differential-element-stress matrix
SDSWDB : Substructure-differential-allowable-stress
SDZBDB : Substructure-dzbdb matrix (dZ_b/db for ith substructure)
SDZIDB : Substructure-dzidb matrix (dZ_i/db for ith substructure)
SDZZDB : Global-dz/db matrix (dZ/db)
SFBGRD : Effective-force gradients (C^* - matrix)
SFIGRD : Substructure-internal-force gradient (C_2 - matrix)
SHESMT : Hessian matrix of augmented lagrangian
SNSTVY : Sensitivity matrix
SSCDB : Substructure-differential-element-damping matrix (dC/db)

6.4 DESIGN OF STRUCTURAL ANALYSIS AND DESIGN OPTIMIZATION DATA SETS

In this section description of data sets in each data group is presented. Sequence of data sets is based on the data flow given in Section 6.2.

CTITLE : TITLE OF THE PROBLEM

Structure Name	Descriptions	Designer Name	Job Name
CHAR	CHAR	CHAR	CHAR

CINTCL : INTEGER CONTROL INFORMATION

Variable Name	Integer value
CHAR	INT

CREAL : REAL CONTROL INFORMATION

Varible Name	Real Value
CHAR	R

CDSIIF : DESIGN-OPTIMIZATION-INTEGER-CONTROL INFORMATION

Control Parameter	Index
CHAR	INT

CDSRIF : DESIGN-OPTIMIZATION-REAL-CONTROL INFORMATION

Control Parameter	Value
CHAR	R

CLGPNA : LAGRANGE MULTIPLIERS AND PENALTY PARAMETERS

Active Constraint Number	Lagrange Multipliers	Penalty Parameters
INT	R	R

ACORDC : NODE-COORDINATE FOR MASTER STRUCTURE

Node	Sys	Cord	Disp	B.C	Skew	Mid-Sur.	Coordinate		
Number	Node	System	Constr	I.C	Coord	Vector			
	No	Type	Code	No.	No.	Set no.	X	Y	Z
INT	INT	CHAR	INT	INT	INT	INT	R	R	R

Boundary Code					
X	Y	Z	R_x	R_y	R_z
I	I	I	I	I	I

ACORDS : NODE-COORDINATE FOR SUBSRTUCTURE(S)

Substr	Node	Sys	B.I	Coord	Disp	Skewd	Mid-Sur.	Coord		
No.	No.	Node	I.C	Sys	Const	Coord	Vector	X	Y	Z
			No.	Type	Code	No	Set No.			
INT	INT	INT	INT	INT	INT	INT	INT	R	R	R

Boundary Condition					
X	Y	Z	T_x	T_y	T_z
I	I	I	I	I	I

ASUBGI : SUBSTRUCTURAL GENREAL INFORMATION

Substr No.	No of Reused Substr	No of Elem	No of Nodes	No of Nodes Condens	No of Nodes Retained	No of Mid-sur Vector	Fixed Design Flag	Damage Flag
INT	INT	INT	INT	INT	INT	INT	INT	INT

ASKEW : SKEW COORDINATE SYSTEM DEFINTION

Skew Coord System No	Skew System Code(Euler)	Projection of a Vector or Euler Angle
INT	INT	R R R R R R

AMIDS : MID-SURFACE NORMAL VECTOR INFORMATION

Mid Surface Set No.	Projection of Normal Vector on X Y Z Axes
INT	RVEC

ANODTM : NODE-TEMPERATURE

Subst Number	Node Number	Load case Number	Temperature
INT	INT	INT	R

ACODCM : NODE-DAMPING AND MASS MATRIX

Node	Substr	Concentrated Mass						Damping Coefficint					
No.	No.	M_x	M_y	M_z	M_{xx}	M_{yy}	M_{zz}	C_x	C_y	C_z	C_{xx}	C_{yy}	C_{zz}
INT	INT	R	R	R	R	R	R	R	R	R	R	R	R

ABCIIC : BOUNADRY CONDITION AND INTIAL CONDITION INFORMATION

I.C. B.C NO.	Time	D.O.F Number	Initial and Boundary Condition Z	Z'	Z"
INT	R	INT	RVEC		

ANODDF : NODE-DOF GLOBAL STRUCTURE

```
==================================================================
= Node    Global      Degree of Freedom Numbers (Equation Numbers) =
= Number  Node       -------------------------------------------  =
=         Number      1   2   3   4   5   6                        =
=.................................................................=
= INT     INT         IVEC                                         =
==================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
==================================================================
```

ASUBDF: NODE-DOF SUBSTRUCTURE(S)

```
===================================================================
=Substr   Substr   Global    Degree of Freedom                     =
=Number   Node     Node      Numbers (Equation Numbers)            =
=         Number   Number                                          =
=                            ---------------------------           =
=                            1   2   3   4   5  6                  =
=..................................................................=
=INT       INT      INT                         IVEC               =
===================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
===================================================================
```

AELCON : ELEMENT-CONNECTIVITY

```
==================================================================
= Element Design VR. Number   No. of      Element Connectivity    =
= Number  Group No.  of Node  Corner Node --------------------    =
=.....................................(User node numbers)......=
= INT     INT        CHAR     IVEC        IVEC                    =
==================================================================
=                                                                 =
=                                                                 =
=                                                                 =
=                                                                 =
=                                                                 =
=                                                                 =
==================================================================
```

AELGNI : ELEMENT GENERAL INFORMATION

```
====================================================================
= Element  Element  Element     Material  Element      Order of    =
= Number   Type    Nonlinearity  Group    Damage   Integration Dir =
=                  Indicator     Number   Flag      R   S    T     =
=                                                   ---------------=
=..................................................................=
= INT       CHAR      INT         INT      INT         INT         =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

AELPRO : ELEMENT-PROPERTIES

```
===================================================================
= Design         Element Properties                  Index for    .
= Variable ------------------------------------------Composite    .
= Group No              RVEC                         Material     .
=..................................................................
=                                                                 .
= INT      REAL   REAL   R   R     REAL   REAL   REAL INT         .
===================================================================
```

```
===================================================================
. Element            No of Design                                 =
. Cross-Sectional     Variables                                   =
. General Infor.        In c/s                                    =
..................................................................=
. CHAR/REAL/INT            INT                                    =
===================================================================
.                                                                 =
.                                                                 =
.                                                                 =
.                                                                 =
.                                                                 =
.                                                                 =
===================================================================
```

AELPRO : ELEMENT-PROPERTIES (AN EXAMPLE FOR BEAM ELEMENT)

```
====================================================================
= Design         Element Properties                  Index for     .
= Variable ------------------------------------------ Composite     .
= Group No Thick  Area  ASy ASx     M.Ix   M.Iy   Ip  Material      .
=...................................................................
=                                                                   .
= INT      REAL   REAL   R   R     REAL   REAL   REAL INT           .
====================================================================



====================================================================
. Element        No of Design   Design  Coord    Coord Orinenta     =
. Cross-Section  Variables     Variable of       of    -tion        =
. Type           In c/s        Numbers  Centroid Shear              =
...................................................................=
. CHAR           INT            IVEC     REAL    REAL   REAL        =
====================================================================
.                                                                   =
.                                                                   =
.                                                                   =
.                                                                   =
.                                                                   =
.                                                                   =
====================================================================
```

AMATPR : RELATED LINEAR MATERIAL PROPERTIES

```
=====================================================================
= Material    Material   Temperature    Material  Properties        .
= Number      Model No.                --------------------        .
=                                                                   .
=...................................................................
= INT          INT          REAL            RVEC                    .
=====================================================================



=====================================================================
. Density   Thermal   Cost Factor                                   .
.           Coeff.    for Design                                    .
---------------------------------------------------------------------
.  REAL      REAL      REAL                                         .
=====================================================================
.                                                                   .
.                                                                   .
=====================================================================



=====================================================================
.      Stress Limits          Shear Stress Limit    Shear           .
. --------------------        ------------------    Factor          .
. Prin.Dir      Minor Dir.                                          .
. Tens. Comp.   Tens. Comp.                                         .
.                                                                   .
.....................................................................
. REAL             REAL              REAL              REAL         .
=====================================================================


=====================================================================
. Normal Stiffness     Shear Stiffness                              =
. Reduction Factor     Reduction Factor                             =
.                                                                   =
..................................................................  =
.       REAL              REAL                                      =
==================================================================  =
.                                                                   =
.                                                                   =
.                                                                   =
.                                                                   =
.                                                                   =
.                                                                   =
=====================================================================
```

AMATPR : RELATED LINEAR MATERIAL PROPERTIES (AN EXAMPLE)

Material Number	Material Model No.	Temperature	Material Properties				
			E_{11}	E_{22}	E_{33}	ν_{12}	ν_{23}
INT	INT	REAL	R	R	R	R	R

				Density	Thermal Coeff.	Cost Factor For Design
ν_{13}	G_{12}	G_{23}	G_{31}			
R	R	R	R	REAL	REAL	REAL

Stress Limits				Shear Stress Limit	Shear Factor
Prin.Dir		Minor Dir.			
Tens.	Comp.	Tens.	Comp.		
REAL		REAL		REAL	REAL

Normal Stiffness Reduction factor	Shear Stiffness Reduction Factor
REAL	REAL

ANONMT1: NONLINEAR MATERIAL TYPE 1

```
=====================================================================
= Material     Material  Type of  No. of   Temperature   Young's    .
= Number       Model No. Yield    Table    Table         Modulus    .
=                        Criteria Points                 Table      .
=....................................................................
=  INT          INT       INT      INT       RVEC          RVEC     .
=====================================================================
 .                                                                  .
 .                                                                  .
 .                                                                  .
 ====================================================================


 ====================================================================
. Possion's    Mean thermal   Stress   Strian   Yield   Strain      .
. Ratio        Coefficient    Table    Table    Stress  Hardening   .
. Table        Table                            Table   Table       .
.....................................................................
. RVEC           RVEC         RVEC     RVEC     RVEC    RVEC
=====================================================================
 .                                                                  .
 .                                                                  .
 .                                                                  .
 ====================================================================


 ====================================================================
 . Creep   No. of Creep    Creep Law                                =
 . Law     Law Constants   Constants                                =
 . No.                                                              =
 ...................................................................=
 . INT     INT                RVEC                                  =
 .===================================================================
 =                                                                  =
 =                                                                  =
 =                                                                  =
 =                                                                  =
 =                                                                  =
 =                                                                  =
 ====================================================================
```

ANONMT2 : NONLINEAR MATERIAL TYPE 2

```
====================================================================
= Material  Material   No. of   Volume    Loading Bulk   Unloading    .
= Number    Model No.  Table    Strain      Modulus      Bulk Modulus.
=                      Points   Table       Table          Table      .
=.....................................................................
= INT        INT        INT      RVEC      RVEC           RVEC        .
====================================================================
 .                                                                    .
 .                                                                    .
 .                                                                    .
 ===================================================================


 ===================================================================
. Loading Shear                                                       =
.    Modulus                                                          =
.    Table                                                            =
.                                                                     =
.....................................................................=
.  RVEC                                                               =
====================================================================
.                                                                     =
.                                                                     =
.                                                                     =
.                                                                     =
.                                                                     =
.                                                                     =
====================================================================
```

ACOMPR : COMPOSITE-ELEMENT PROPERTIES (LAYERED)

```
===================================================================
= Index for No    No of Stress Fiber Direc.  Thickns. Mat.   Thick  =
= Composite of    Point/Layer  for Each Lay  of Each  Interp Interp =
= Material  Layer              ------------  Layer    Factor Factor =
=..................................................................=
=                                   .                               =
= INT         INT       RVEC      RVEC         RVEC     RVEC   RVEC  =
===================================================================
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
===================================================================
```

ADYNLD : DYNAMIC LOAD DEFINITION

Time Function Number	No. of Table Points	Time Table	Fuction Value Table
INT	INT	RVEC	RVEC

ANODLD : EQUIVALENT NODE-LOAD DATA FOR THE MASTER STRUCTURE

Node Number	Equation Number	Load Case Number	Load Type	Time Table Number	Load Value (Static)	Fuction Multiplier/ Pressure Multipliers	Arrival Time
I	I	I	I	I	R	R/RVEC	R

AELLOD : ELEMENT-LOAD DATA FOR MASTER STRUCTURE

```
=====================================================================
= Element    Load  Load    Load  Time Table                        =
= Number     Dir.  Case    Type    Number                          =
=..................................................................=
=   I         I     I       I       I                              =
=====================================================================
```

```
=====================================================================
. Load Values( Static )     Fuction Multiplier/     Arrival        =
. Begin...End.....Mid...    Pressure multipliers     Time          =
...................................................................=
. R       R       R            R/RVEC                  R           =
.====================================================================
.                                                                  =
.                                                                  =
.                                                                  =
.                                                                  =
.                                                                  =
.                                                                  =
=====================================================================
```

AINLOD : INERTIA NODE-LOAD

```
=====================================================================
=Time Function     Equation          Direction                     =
=Number            Number            Multiplier                    =
=                                                                  =
=..................................................................=
=  INT               INT               R                           =
=====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=====================================================================
```

ASNOLD : EQUIVALENT NODE-LOAD DATA FOR SUBSTRUCTURE(S)

```
=====================================================================
= Substr. Reused Node   Equation  Load Case Load   Time   Load Value.
= Number  Sustr. Number  Number    Number   Type   Table  ( Static ).
=         Number                                   Number           .
=....................................................................
=  I        I       I        I        I       I      I       R      .
=====================================================================
```

```
=====================================================================
. Fuction Multiplier/     Arrival                                   =
. Pressure Multipliers     Time                                     =
.                                                                   =
....................................................................=
.     R/RVEC                  R                                     =
=====================================================================
.                                                                   =
.                                                                   =
.                                                                   =
.                                                                   =
.                                                                   =
.                                                                   =
=====================================================================
```

ASELLOD : ELEMENT-LOAD DATA FOR SUBSTRUCTURE(S)

```
=====================================================================
= Substr. Reused  Element   Load  Load    Load   Time Table         .
= Number  Substr. Number    Dir.  Case    Type     Number           .
=         Number                                                    .
=....................................................................
=   I      I        I        I     I       I        I               .
=====================================================================
```

```
=====================================================================
. Load Values( Static )     Fuction Multiplier/      Arrival        =
. Begin...End.....Mid...    Pressure Multipliers      Time          =
....................................................................=
. R       R       R           R/RVEC                   R            =
.====================================================================
.                                                                   =
.                                                                   =
.                                                                   =
.                                                                   =
.                                                                   =
.                                                                   =
=====================================================================
```

AISTEL INITIAL STRESS VECTOR (ELEMENT)

```
====================================================================
=  Substr.   Element  Load  Layer     Element Stress               =
=  Number    Number   Case  Number     Vector                      =
= ..................................................................=
=    I         I       I      I          RVEC(6)                   =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

AISREL : INITIAL STRAIN VECTOR (ELEMENT)

```
====================================================================
= Substr.   Element  Load  Layer     Element Strain                =
= Number    Number   Case  Number     Vector                       =
= ..................................................................=
=  I          I        I     I          RVEC(6)                    =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

ASESMT : SUBSTRUCTURE ELEMENT-STIFFNESS MATRIX (LINEAR)

```
====================================================================
= Subst.  Element   Matrix  Matrix                                 =
= Number  Number    Type    Size      Element Stiffness Matrix     =
=...................................................................=
= I         I       CHAR     I                   DMAT              =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

AELMAT : ELEMENT-STIFFNESS MATRIX (LINEAR)

```
====================================================================
= Element   Matrix  Matrix                                         =
= Number    Type    Size           Element Stiffness Matrix        =
=..................................................................=
= I          CHAR     I            DMAT                            =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

ASETRM : SUBSTRUCTURE ELEMENT-TRANSFORMATION MATRIX

```
====================================================================
= Subst.  Element   Matrix  Row  Column                            =
= Number  Number     Type   Size  Size  Element Transform. Matrix  =
=..................................................................=
= I         I        CHAR     I     I   DMAT                       =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

AELTRF : ELEMENT-TRANSFORMATION MATRIX

```
====================================================================
= Element   Matrix  Row  Column                                    =
= Number    Type   Size  Size      Element Transformation Matrix   =
=..................................................................=
= I          CHAR   I     I        DMAT                            =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

ASSBIN : ASSEMBLED SUBSTRUCTURE STIFFNESS MATRIX (INTERNAL)

```
====================================================================
= Substr    Hypermatrix   Null    Stiffness Submatrix              =
= Number   Row    Column  Index                                    =
=..................................................................=
=  I       I         I      I      DMAT                            =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

ASSBBN : ASSEMBLED SUBSTRUCTURE STIFFNESS MATRIX (BOUNDARY)

```
====================================================================
= Substr    Hypermatrix   Null    Stiffness Submatrix              =
= Number   Row    Column  Index                                    =
=..................................................................=
=  I       I         I     I       DMAT                            =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

ASSBIB : ASSEMBLED SUBSTRUCTURE STIFFNESS MATRIX (INTERNAL-BOUNDARY)

```
====================================================================
= Substr    Hypermatrix   Null    Stiffness Submatrix              =
= Number   Row    Column  Index                                    =
=..................................................................=
=  I       I         I      I      DMAT                            =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

ACSSMT : CONDENSED SUBSTRUCTURE STIFFNESS MATRIX

```
================================================================
= Substr   Hypermatrix  Null    Stiffness Submatrix            =
= Number  Row     Column Index                                 =
=..............................................................=
=  I       I        I     I       DMAT                         =
================================================================
=                                                              =
=                                                              =
=                                                              =
=                                                              =
=                                                              =
=                                                              =
================================================================
```

ASELMS : SUBSTRUCTURE ELEMENT-MASS MATRIX (LUMPED/DIAGONAL)

```
================================================================
= Substr.    Element    Matrix        Element Mass Matrix      =
= Number     Number     Size              (Diagonal)           =
=..............................................................=
= I            I         I                  DVEC               =
================================================================
=                                                              =
=                                                              =
=                                                              =
=                                                              =
=                                                              =
=                                                              =
=                                                              =
================================================================
```

AELMAS : ELEMENT-MASS MATRIX (LUMPED/DIAGONAL)

```
================================================================
= Element           Matrix            Element Mass Matrix      =
= Number            Size                  (Diagonal)           =
=..............................................................=
= I                  I                DVEC                     =
================================================================
=                                                              =
=                                                              =
=                                                              =
=                                                              =
=                                                              =
=                                                              =
=                                                              =
================================================================
```

ASEMMC : SUBSTRUCTURE ELEMENT-MASS MATRIX (CONSISTENT)

```
====================================================================
= Substr.   Element   Matrix  Matrix                               =
= Number    Number    Type    Size        Element Mass  Matrix     =
=..................................................................=
=   I          I      CHAR     I               DMAT                =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

AELMSC : ELEMENT-MASS MATRIX (CONSISTENT)

```
====================================================================
= Element   Matrix  Matrix                                         =
= Number    Type    Size                Element Mass Matrix        =
=..................................................................=
= I          CHAR     I                   DMAT                     =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

AMASHY : ASSEMBLED SUBSTRUCTURE MASS MATRICES (INTERNAL)

```
====================================================================
= Substr    Hypermatrix   Null   Mass Submatrix                    =
= Number   Row    Column  Index                                    =
=..................................................................=
=  I        I         I     I       DMAT                           =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

ASMBON : ASSEMBLED SUBSTRUCTURE MASS MATRICES (BOUNDARY)

```
====================================================================
= Substr    Hypermatrix   Null    Mass Submatrix                   =
= Number   Row     Column  Index                                   =
=..................................................................=
=  I        I          I      I        DMAT                        =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

ASMINB : ASSEMBLED SUBSTRUCTURE MASS MATRICES (INTERNAL-BOUNDARY)

```
====================================================================
= Substr    Hypermatrix   Null    Mass Submatrix                   =
= Number   Row     Column  Index                                   =
=..................................................................=
=  I        I          I      I        DMAT                        =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

ACSSMT : CONDENSED SUBSTRUCTURE MASS MATRIX

```
====================================================================
= Substr    Hypermatrix   Null     Mass Submatrix                  =
= Number   Row     Column  Index                                   =
=..................................................................=
=  I        I          I       I       DMAT                        =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

ASDMAT : SUBSTRUCTURE DAMPING MATRIX (INTERNAL)

```
================================================================
= Substr   Hypermatrix  Null   Damping  Submatrix              =
= Number  Row    Column  Index                                 =
=..............................................................=
=  I      I         I     I      DMAT                          =
================================================================
=                                                              =
=                                                              =
=                                                              =
=                                                              =
=                                                              =
=                                                              =
================================================================
```

ASDMTB : SUBSTRUCTURE DAMPING MATRIX (BOUNDARY)

```
================================================================
= Substr   Hypermatrix  Null   Damping  Submatrix              =
= Number  Row    Column  Index                                 =
=..............................................................=
=  I      I         I     I      DMAT                          =
================================================================
=                                                              =
=                                                              =
=                                                              =
=                                                              =
=                                                              =
================================================================
```

ACSDMT : CONDENSED SUBSTRUCTURE DAMPING MATRIX

```
================================================================
= Substr   Hypermatrix  Null    Damping Submatrix              =
= Number  Row    Column  Index                                 =
=..............................................................=
=  I      I         I     I      DMAT                          =
================================================================
=                                                              =
=                                                              =
=                                                              =
=                                                              =
=                                                              =
=                                                              =
=                                                              =
================================================================
```

AESSMT : EFFECTIVE SUBSTRUCTURE STIFFNESS MATRIX (DYNAMICS)

```
====================================================================
= Substr    Hypermatrix   Null    Stiffness Submatrix              =
= Number   Row    Column  Index                                    =
=..................................................................=
=  I       I         I     I       DMAT                            =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

ADSSMT : DECOMPOSED EFFECTIVE SUBSTRUCTURE STIFFNESS MATRIX

```
====================================================================
= Substr    Hypermatrix   Null    Stiffness Submatrix              =
= Number   Row    Column  Index                                    =
=..................................................................=
=  I       I         I     I       DMAT                            =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

ASLSMT : ASSEMBLED LINEAR STIFFNESS MATRIX (GLOBAL)

```
====================================================================
=           Hypermatrix   Null    Stiffness Submatrix              =
=          Row    Column  Index                                    =
=..................................................................=
=          I         I     I       DMAT                            =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

ASLMMT : ASSEMBLED MASS MATRIX (GLOBAL)

```
====================================================================
=           Hypermatrix   Null    Mass Submatrix                   =
=          Row    Column  Index                                    =
=..................................................................=
=          I         I     I       DMAT                            =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

ASLDMT : ASSEMBLED DAMPING MATRIX (GLOBAL)

```
====================================================================
=           Hypermatrix   Null    Damping Submatrix                =
=          Row    Column  Index                                    =
=..................................................................=
=          I         I     I       DMAT                            =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

AELHYP : EQUATION NUMBERS CONTRIBUTING TO A HYPERMATRIX

```
====================================================================
= Substr      Hypermatrix       Equation Numbers                   =
= Numbers    Row   Column                                          =
=..................................................................=
=   I         I       I             IVEC                           =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

ADLSMT : DECOMPOSED LINEAR STIFFNESS MATRIX (GLOBAL)

```
==================================================================
=          Hypermatrix   Null    Stiffnes Submatrix              =
=         Row    Column  Index                                   =
=................................................................=
=          I        I      I       DMAT                          =
==================================================================
=                                                                =
=                                                                =
=                                                                =
=                                                                =
=                                                                =
=                                                                =
=                                                                =
=                                                                =
==================================================================
```

AELSMT : EFFECTIVE LINEAR STIFFNESS MATRIX (GLOBAL-DYANMICS)

```
==================================================================
=          Hypermatrix   Null    Stiffnes Submatrix              =
=         Row    Column  Index                                   =
=................................................................=
=          I        I      I       DMAT                          =
==================================================================
=                                                                =
=                                                                =
=                                                                =
=                                                                =
=                                                                =
=                                                                =
==================================================================
```

ADESMT : DECOMPOSED EFFECTIVE LINEAR STIFFNESS MATRIX
(GLOBAL-DYANMICS)

```
==================================================================
=          Hypermatrix   Null    Stiffnes Submatrix              =
=         Row    Column  Index                                   =
=................................................................=
=          I        I      I       DMAT                          =
==================================================================
=                                                                =
=                                                                =
=                                                                =
=                                                                =
=                                                                =
=                                                                =
=                                                                =
==================================================================
```

ASLOMI : SUBSTRUCTURE LOAD MATRIX (INTERNAL) FOR LINEAR S1ATICS

```
====================================================================
= Substr  Reused        Hypermatrix  Null    Load Submatrix        =
= Number Subst. No.     Row   Coumn  Index                         =
=..................................................................=
=  I       I              I     I      I          DMAT             =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

ASLOMB : SUBSTRUCTURE LOAD MATRIX (BOUNDARY) FOR LINEAR STATICS

```
====================================================================
= Substr   Reused       Hypermatrix   Null       Load  Submatrix   =
= Number  Subst. No.  Row    Column   Index                        =
=..................................................................=
=  I         I          I      I        I             DMAT         =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

ASCLMT : CONDENSED LOAD MATRIX (SUBSTRUCTURE) FOR LINEAR STATICS

```
====================================================================
= Substr   Reused         Hypermatrix   Null    Load Submatrix     =
= Number  Subst. No.    Row    Column   Index                      =
=..................................................................=
=  I        I             I         I     I         DMAT           =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

AAGLMT : ASSEMBLED LOAD MATRIX (GLOBAL) FOR LINEAR STATICS

```
====================================================================
=           Hypermatrix   Null    Load  Submatrix                  =
=          Row    Column  Index                                    =
=..................................................................=
=          I         I             DMAT                            =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

ASLIMT : SUBSTRUCTURE LOAD MATRIX (INTERNAL)

```
====================================================================
= Substr  Reused   Load   Hyper-  Time   Null    Load  Vector      =
= Number Subst No. Case    Row    Value  Index                     =
=..................................................................=
=  I       I        I       I       R       I      DVEC            =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

AALBMT : SUBSTRUCTURE LOAD MATRIX (BOUNDARY)

```
====================================================================
= Substr  Reused   Load    Hyper-  Time   Null    Load  Vector     =
= Number Subst. No Case     Row    Value  Index                    =
=..................................................................=
=  I        I        I       I       R       I      DVEC           =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

ACLDMT : CONDENSED LOAD MATRIX FOR LINEAR DYNAMICS/NONLINEAR STATICS

```
====================================================================
= Substr  Reused     Load    Hyper-  Time     Null    Load  Vector  =
= Number Subst. No. Case    Row     Value    Index                 =
=..................................................................=
=  I         I         I       I       R        I       DVEC        =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

AGLDMT : GLOBAL LOAD MATRIX FOR LINEAR/NONLINEAR DYNAMICS

```
====================================================================
= Load     Hyper-  Time     Null     Load  Vector                  =
= Case      Row    Value    Index                                  =
=..................................................................=
=  I        I        R        I        DVEC                        =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

AELDMT : EFFECTIVE SUBSTRUCTURE LOAD MATRIX FOR LINEAR DYNAMICS

```
====================================================================
= Substr Reused      Load      Hyper-  Time     Null    Load  Vector =
= Number Subst. No. Case        Row    Value    Index              =
=..................................................................=
=  I        I         I           I       R        I       DVEC     =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

AGELMT : GLOBAL EFFECTIVE LOAD MATRIX FOR LINEAR/NONLINEAR DYNAMICS

```
====================================================================
= Load    Hyper-  Time    Null    Load  Vector                     =
= Case     Row    Value   Index                                    =
=..................................................................=
=  I       I       R       I       DVEC                            =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

ASTNEL : ELEMENT STIFFNESS MATRIX (NONLINEAR)

```
====================================================================
= Element  Matrix  Matrix         Element Stiffness                =
= Number   Type    Size           Matrix                           =
= .................................................................=
=  I       CHAR     I                   DMAT                       =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

ANSTMT: ASSEMBLED NONLINEAR STIFFNESS MATRIX

```
====================================================================
= Load Time   Hypermatrix         Null        Stiffness Submatrix  =
= Case Step   Row   Column        Index                            =
=..................................................................=
=   I   I      I       I           I            DMAT               =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

AFTGSM : FINAL TANGENTIAL GLOBAL STIFFNESS MATRIX

```
======================================================================
= Load  Time   Hypermatrix  Null        Stiffness Submatrix          =
= Case  Step   Row   Column Index                                    =
=....................................................................=
=   I     I      I      I      I                DMAT                 =
======================================================================
=                                                                    =
=                                                                    =
=                                                                    =
=                                                                    =
=                                                                    =
=                                                                    =
=                                                                    =
======================================================================
```

ADFTGS : DECOMPOSED FINAL TANGENTIAL GLOBAL STIFFNESS MATRIX

```
======================================================================
= Load  Time   Hypermatrix  Null        Stiffness Submatrix          =
= Case  Step   Row   Column Index                                    =
=....................................................................=
=   I     I      I      I      I                DMAT                 =
=                                                                    =
======================================================================
=                                                                    =
=                                                                    =
=                                                                    =
=                                                                    =
=                                                                    =
=                                                                    =
======================================================================
```

AFTESM : FINAL TANGENTIAL EFFECTIVE STIFFNESS MATRIX

```
======================================================================
= Load  Time  Hypermatrix   Null        Stiffness Submatrix          =
= Case  Step  Row   Column  Index                                    =
=....................................................................=
=   I      I    I      I       I               DMAT                  =
======================================================================
=                                                                    =
=                                                                    =
=                                                                    =
=                                                                    =
=                                                                    =
=                                                                    =
=                                                                    =
======================================================================
```

ADFTES : DECOMPOSED FINAL TANGENTIAL EFFECTIVE STIFFNESS MATRIX

```
=====================================================================
= Load   Time  Hypermatrix     Null         Stiffness Submatrix     =
= Case   Step  Row    Column   Index                                =
=...................................................................=
=   I      I     I      I        I                DMAT              =
=====================================================================
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
=====================================================================
```

AEGVEC : EIGENVALUES AND EIGENVECTORS

```
=====================================================================
= Damage    Mode    Eigen-   Vector               Eigenvectors      =
= Cond.No.  Number  Values   Size                                   =
=...................................................................=
=    I        I       R        I                    DVEC            =
=====================================================================
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
=====================================================================
```

AGESMT : GENERALIZED STRUCTURAL MATRICES FOR MODAL ANALYSIS

```
=====================================================================
= Mode    Generalized   Generalized   Generalized                   =
= Number  Stiffness        Mass         Damping                     =
=.................................................................. =
=  I         R               R              R                       =
=====================================================================
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
=====================================================================
```

ABUCEL : BUCKLING LOAD FACTOR AND MODE SHAPE

```
====================================================================
= Load     Vector  Load           Element Mode Shape Vector        =
= Case No. Size    Factor                                          =
= .................................................................=
=  I         I      I                 IVEC                         =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

ADISPLG : DISPLACEMENT MATRIX (GLOBAL)

```
====================================================================
=           Hypermatrix   Null    Displacement Submatrix           =
=          Row    Column  Index                                    =
=..................................................................=
=          I         I             DMAT                            =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

ADGIDN : DISPLACEMENT MATRIX (GLOBAL) FOR LINEAR/NONLINEAR DYNAMICS

```
====================================================================
=         Hyper-  Time    Null    Displacement Vector              =
=          Row   Value    Index                                    =
=..................................................................=
=          I       R       I       DVEC                            =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

AASIDN : ACCELERATION VECTOR (GLOBAL) FOR DYNAMICS/NONLINEAR

```
==============================================================
=        Hyper-  Time    Null    Acceleration Vector         =
=         Row    Value   Index                               =
=............................................................=
=         I       R       I       DVEC                       =
==============================================================
=                                                            =
=                                                            =
=                                                            =
=                                                            =
=                                                            =
=                                                            =
==============================================================
```

AVELDN : VELOCITY VECTOR (GLOBAL)

```
==============================================================
=        Hyper-  Time    Null    Velocity Vector             =
=         Row    Value   Index                               =
=............................................................=
=         I       R       I       DVEC                       =
==============================================================
=                                                            =
=                                                            =
=                                                            =
=                                                            =
=                                                            =
=                                                            =
==============================================================
```

ASSTEL : SUBSTRUCTURE STRESS VECTOR (ELEMENT)

```
==============================================================
= Subst. Elem. Load Time Layer No. of  Vector Stress Prin.   Angle =
= Number No.   Case Step  No. Strs. Pt Size   Vector Strs.         =
= ................................................................=
=  I      I     I    I     I      I      I    RVEC    RVEC      R  =
==============================================================
=                                                            =
=                                                            =
=                                                            =
=                                                            =
=                                                            =
=                                                            =
==============================================================
```

ASTREL : STRESS VECTOR (ELEMENT)

```
====================================================================
= Elem. Load Time Layer No. of Vector Elem Stress Prin. Strs. Angle=
= No.   Case Step  No. Strs. Pt Size     Vector      Vector        =
= .................................................................=
=  I      I     I    I    I      I     RVEC          RVEC      R   =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

ASSTAL : SUBSTRUCTURE STRAIN VECTOR (ELEMENT)

```
====================================================================
= Substr. Ele. Load Time Layer No. of  Vector Strain Prin.   Angle =
= Number  No.  Case Step No.  Strn. Pt Size   Vector Strain        =
= .................................................................=
=  I      I     I    I    I     I       I    RVEC    RVEC     R    =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

ASTRAL : STRAIN VECTOR (ELEMENT)

```
====================================================================
= Elem.  Load  Time  Layer  No. of    Vector  Strain  Prin.  Angle =
= No.    Case  Step  No.    Str. Pt.  Size    Vector  Strain       =
= .................................................................=
=  I      I   I    I      I       I    RVEC   RVEC   R             =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

ASFOEL : SUBSTRUCTURE ELEMENT NODAL FORCE VECTOR

```
=====================================================================
= Subst. Element Load Time  Node   Vector Force Vector  Resultant  =
= No.    Number  Case Step  No.     Size               Force  Moment=
= .................................................................=
=  I       I       I    I     I       I       RVEC       R      R   =
=====================================================================
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
=====================================================================
```

AFOREL : ELEMENT NODAL FORCE VECTOR

```
=====================================================================
= Element  Load  Time  Node    Vector Force Vector  Resultant       =
= No.      Case  Step   No.     Size               Force  Moment    =
= .................................................................=
=  I         I     I    I       I       RVEC        R       R       =
=====================================================================
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
=====================================================================
```

ASDISB : DISPLACEMENT MATRIX (BOUNDARY)

```
=====================================================================
= Substr Reused     Hypermatrix  Null    Displacement Submatrix     =
= Number Subsr.No.  Row  Column  Index                              =
=..................................................................=
=  I       I          I     I      I             DMAT               =
=====================================================================
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
=====================================================================
```

ASDISI : SUBSTRUCTURE DISPLACEMENT MATRIX (INTERNAL)

```
====================================================================
= Substr Reused     Hypermatrix  Null    Displacement Submatrix    =
= Number Subsr.No.  Row  Column  Index                             =
=..................................................................=
=  I       I         I     I       I           DMAT                =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

ADSIDN : DISPLACEMENT MATRIX (INTERNAL) FOR DYNAMICS

```
====================================================================
= Substr  Reused   Hyper   Time    Null    Displacement Vector     =
= Number Subst.No. Row     Value   Index                           =
=..................................................................=
=  I       I       I        R       I          RVEC                =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

ASDISB : SUBSTRUCTURE DISPLACEMENT MATRIX (BOUNDARY)

```
====================================================================
= Substr  Reused   Hyper   Time    Null    Displacement Vector     =
= Number Subst.No. Row     Value   Index                           =
=..................................................................=
=  I       I       I        R       I          RVEC                =
====================================================================
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
=                                                                  =
====================================================================
```

ASAIDN : SUBSTRUCTURE ACCELERATION VECTOR (INTERNAL)

```
==================================================================
= Substr  Reused    Hyper  Time    Null   Acceleration Vector    =
= Number Subst.No.   Row   Value   Index                         =
=................................................................=
=  I        I         I     R       I       DVEC                 =
==================================================================
=                                                                =
=                                                                =
=                                                                =
=                                                                =
=                                                                =
=                                                                =
==================================================================
```

ASABDN : SUBSTRUCTURE ACCELERATION VECTOR (BOUNDARY)

```
==================================================================
= Substr  Reused    Hyper  Time    Null   Acceleration Vector    =
= Number Subst.No.   Row  Value    Index                         =
=................................................................=
=  I        I         I     R       I       DVEC                 =
==================================================================
=                                                                =
=                                                                =
=                                                                =
=                                                                =
=                                                                =
=                                                                =
==================================================================
```

ASVIDN : SUBSTRUCTURE VELOCITY VECTOR (INTERNAL)

```
==================================================================
= Substr  Reused    Hyper  Time    Null   Accelaration Vector    =
= Number Subst.No. Row     Value   Index                         =
=................................................................=
=  I        I        I      R        I           RVEC            =
==================================================================
=                                                                =
=                                                                =
=                                                                =
=                                                                =
=                                                                =
=                                                                =
==================================================================
```

ASABDN : SUBSTRUCTURE ACCELERATION VECTOR (BOUNDARY)

```
====================================================================
= Substr  Reused     Hyper   Time     Null     Accelaration Vector  =
= Number Subst. No.  Row     Value    Index                         =
=..................................................................=
=  I       I          I       R        I           RVEC             =
====================================================================
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
====================================================================
```

DACNIF : CONSTRAINT INFORMATION

```
=======================================================================.
= Constraint Constraint  Substr. Reused   Constraint Loading  Point   .
= Number     Type        Number  Substr.  ID Number  Case     Number  .
=                                Number              Number           .
=.......................................................................
=   I          CHAR        I       I         I         I        I     .
=======================================================================


.======================================================================
.  Time    Value    Constraint                                        =
.   Tj              Status                                            =
.                 Active/Inactive                                     =
......................................................................=
.   R        R        I                                               =
.======================================================================
.                                                                     =
.                                                                     =
.                                                                     =
.                                                                     =
.                                                                     =
.                                                                     =
.======================================================================
```

Remark:

```
         Constraint Type = 1 : Stress constraint , ID Number = Element no.
                         = 2 : Displ. constraint , ID Number = Equation no.
                         = 3 : Freq.  constraint , ID Number = Frequency no.
                         = 4 : Buckl. constraint , ID Number = NA
                         = 5 : Displ. constraint , ID Numner = Nodal no.
                               (ball type boundary)
                         = 6 : User supplied constraint ID Number =
                                                           constraint no.
```

DDSPLT : DISPLACEMENT-LIMITS

Displacement Constraint Code Number	Displacement Limits						
	Norm	OR	For Each DOF				
	|Z|	X	Y	Z	RX	RY	RZ
I	R	R	R	R	R	R	R

DALWST : ELEMENT-ALLOWABLE-STRESSES

Element Number	Unbraced Length		Effect. Length Factor		Vector Length	Computed Allowable Stress &
	L_x	L_y	K_x	K_y		F_{bx} F_{by} F_s F_{ex} F_{ey} C_{mx} C_{my} F_a (ALWST(I),I=1,NS)
I	R	R	R	R	I	RVEC

DFRQLT : FREQUENCY LIMITS

Freqency Number	Lower Bound	Upper Bound
I	R	R

SCSTGD : COST-GRADIENT

Design Variable Number	Cost Function Gradient Coefficients	
	Last	Current
INT	R	R

SCNSGD : CONSTRAINT-GRADIENT

Constraint Number	Global Equation Number	Nonzero Gradient at Tj	Constraint Values at T - Tj
I	I	R	R

SDCIDZ : SUBSTRUCTURE-INTERNAL-CONSTRAINT-GRADIENT

Substr. Number	Reused Substr. Number	Constraint Number	Substr. Equation Number	Nonzero Gradient at Tj	Constraint Values at T - Tj
I	I	I	I	R	R

SDCBDZ : SUBSTRUCTURE-BOUNDARY-CONSTRAINT-GRADIENT

```
==========================================================================
= Substr.  Reused  Constraint  Substr.    Nonzero Constraint             =
= Number   Substr. Number      Equation   Gradient Values                =
=          Number              Number     at Tj    at T - Tj             =
=.......................................................................=
=    I        I        I          I          R          R                =
==========================================================================
=                                                                        =
=                                                                        =
=                                                                        =
=                                                                        =
=                                                                        =
=                                                                        =
==========================================================================
```

SDDCDZ : DIFFERENTIAL-CONSTITUTIVE MATRIX (MATERIAL NONLINEAR)

```
==========================================================================
= Element    Global    Matrix      dD/dz                                 =
= Number     Equation  Size     ------------                             =
=            Number                                                      =
=.......................................................................=
=    I         I         I         RMAT                                  =
==========================================================================
=                                                                        =
=                                                                        =
=                                                                        =
=                                                                        =
=                                                                        =
=                                                                        =
==========================================================================
```

SDKSDB : DIFFERENTIAL-ELEMENT-STIFFNESS MATRIX (dKs/db)
(DERIVATIVE OF ELEMENT STIFFNESS MATRICES w.r.t. D.V.)

```
==========================================================================
= Element      Design      Matrix size      dKs/db Coefficients          =
= Number       Variable                                                  =
=              Number                                                    =
=...................................................................... =
=                I           I        I               DMAT               =
==========================================================================
=                                                                        =
=                                                                        =
=                                                                        =
=                                                                        =
=                                                                        =
=                                                                        =
==========================================================================
```

SDKKDB : SUBSTRUCTURE-DIFFERENTIAL-ELEMENT-STIFFNESS MATRIX (dKs/db)
(DERIVATIVE OF ELEMENT STIFFNESS MATRICES w.r.t. D.V.)

```
=====================================================================
=Substr.        Element   Design   Matrix Size dKs/db Coefficients  =
=                         Variable             -------------------- =
=Number          Number   Number                                    =
=.................................................................. =
=   I              I         I         I             DMAT           =
=====================================================================
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
=====================================================================
```

SDKSDZ : DIFFERENTIAL-ELEMENT-STIFFNESS MATRIX (dKs/dz)
(DERIVATIVE OF ELEMENT STIFFNESS MATRICES w.r.t. STATE V.)

```
=====================================================================
=          Element   Global   Matrix Size   dKs/dz Coefficients     =
=                    Equation               ------------------      =
=           Number   Number                                         =
=.................................................................. =
=             I         I        I                DMAT              =
=====================================================================
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
=====================================================================
```

SDSGDB : SUBSTRUCTURE-DIFFERENTIAL-ELEMENT-STRESS MATRIX

```
=====================================================================
=  Substr.   Reused   Element  Design          dσ/db                =
=  Number    Substr.           Variable  --------------------       =
=            Number   Number   Number                               =
=                                                                   =
=...................................................................=
=    I         I        I        I        I         IVEC      RVEC  =
=====================================================================
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
=====================================================================
```

SDEGDB : DIFFERENTIAL-ELEMENT-STRESS MATRIX

```
======================================================================
= Element    Design            dσ/db                                  =
=            Variable      ---------------                            =
= Number     Number                                                   =
=                                                                     =
=....................................................................=
=                      I         I               RVEC                 =
======================================================================
=                                                                     =
=                                                                     =
=                                                                     =
=                                                                     =
=                                                                     =
=                                                                     =
======================================================================
```

SDSBDZ : DIFFERENTIAL-ELEMENT-STRESS-DISPLACEMENT MATRIX (dB/dz)
(NONLINEAR ELEMENT)

```
======================================================================
=  Element  Global       Matrix Size                  dB/dz Coeff.    =
=  Number   Equation --------------------      --------------------- =
=           Number   NO. of Col  No. of Row                           =
=  .................................................................=
=   I          I         I          I                 DMAT            =
======================================================================
=                                                                     =
=                                                                     =
=                                                                     =
=                                                                     =
=                                                                     =
=                                                                     =
======================================================================
```

SDEGDZ : DIFFERENTIAL-ELEMENT-STRESS MATRIX (dSIG/dz)

```
======================================================================
= Element    Global                dσ/dz                              =
= Number     Equation      -------------------------                  =
=            Number                                                   =
=                                                                     =
=....................................................................=
=   I          I                   RVEC                               =
======================================================================
=                                                                     =
=                                                                     =
=                                                                     =
=                                                                     =
=                                                                     =
=                                                                     =
======================================================================
```

SDMDDB : DIFFERENTIAL-ELEMENT-MASS MATRIX (dMd/db)
(DERIVATIVE OF ELEMENT MASS MATRICES w.r.t. D.V.-LUMPED,DIAGON

```
==================================================================
= Element     Design       Matrix Size      dMd/db Coefficients  =
= Number      Variable                      -------------------  =
=             Number                                             =
=............................................................... =
=   I         CHAR           I                    DMAT           =
==================================================================
=                                                                =
=                                                                =
=                                                                =
=                                                                =
=                                                                =
=                                                                =
==================================================================
```

SDSDDB : SUBSTRUCTURE-DIFFERENTIAL-ELEMENT-MASS MATRIX (dMd/db)
(DERIVATIVE OF ELEMENT MASS MATRICES w.r.t. D.V.-CONSISTENT)

```
==================================================================
= Substr.     Element    Design     Matrix Size  dMd/db Coefficients  =
= Number      Number     Variable                -------------------- =
=                        Number                                       =
=.....................................................................=
=   I           I          I           I              DMAT            =
=======================================================================
=                                                                     =
=                                                                     =
=                                                                     =
=                                                                     =
=                                                                     =
=                                                                     =
=======================================================================
```

SDMCDB : DIFFERENTIAL-ELEMENT-MASS MATRIX (dMc/db)
(DERIVATIVE OF ELEMENT MASS MATRICES w.r.t. D.V.-LUMPED,DIAGON)

```
=======================================================================
= Element      Design        Matrix Size      dMd/db Coefficients     =
= Number       Variable                       ------------------      =
=              Number                                                 =
=.....................................................................=
=   I           CHAR            I                   DMAT              =
=======================================================================
=                                                                     =
=                                                                     =
=                                                                     =
=                                                                     =
=                                                                     =
=                                                                     =
=======================================================================
```

SDSCDB : SUBSTRUCTURE-DIFFERENTIAL-ELEMENT-MASS MATRIX (dM_c/db)
(DERIVATIVE OF ELEMENT MASS MATRICES w.r.t. D.V.-CONSISTENT)

```
=========================================================================
= Substr.    Element    Design     Matrix Size   dMc/db Coefficients    =
= Number     Number     Variable                 --------------------   =
=                       Number                                          =
=.......................................................................=
=    I          I          I            I                 DMAT          =
=========================================================================
=                                                                       =
=                                                                       =
=                                                                       =
=                                                                       =
=                                                                       =
=                                                                       =
=========================================================================
```

SDMDDZ : DIFFERENTIAL-ELEMENT-MASS MATRIX (dM_d/dz)
(DERIVATIVE OF ELEMENT MASS MATRICES w.r.t. State V.-lUMPED)

```
=========================================================================
= Element       Global       Matrix Size     dMd/dz Coefficients        =
= Number        Equation                     -------------------        =
=               Number                                                  =
=.......................................................................=
=   I             I             I                  DMAT                 =
=========================================================================
=                                                                       =
=                                                                       =
=                                                                       =
=                                                                       =
=                                                                       =
=                                                                       =
=========================================================================
```

SDMCDZ : DIFFERENTIAL-ELEMENT-MASS MATRIX (dM_c/dz)
(DERIVATIVE OF ELEMENT MASS MATRICES w.r.t. State V.-CONSISTENT

```
=========================================================================
= Element       Global       Matrix Size      dMc/dz Coefficients       =
= Number        Equation                      -------------------       =
=               Number                                                  =
=.......................................................................=
=   I             I              I                  DAMT                =
=========================================================================
=                                                                       =
=                                                                       =
=                                                                       =
=                                                                       =
=                                                                       =
=                                                                       =
=========================================================================
```

SDCEDB : DIFFERENTIAL-ELEMENT-DAMPING MATRIX (dC/db)
(FOR EXAMPLE : ELEMENT DRAG FORCE DAMPING)

```
=======================================================================
=  Element     Design      Matrix              dC/db Coefficients     =
=  Number      Variable    Size          -----------------------------=
=              Number                                                 =
=.....................................................................=
=   I            I            I               RMAT                    =
=======================================================================
=                                                                     =
=                                                                     =
=                                                                     =
=                                                                     =
=                                                                     =
=                                                                     =
=======================================================================
```

SSCDB : SUBSTRUCTURE-DIFFERENTIAL-ELEMENT-DAMPING MATRIX (dC/Db)

```
=======================================================================
=  Substr.   Reused    Element  Design   Matrix        dC/db          =
=  Number    Substr.   Number   Variable Size    -------------------  =
=            Number             Number                                =
=.....................................................................=
=    I         I         I        I        I         DMAT             =
= =====================================================================
=                                                                     =
=                                                                     =
=                                                                     =
=                                                                     =
=                                                                     =
=                                                                     =
=======================================================================
```

SDFEDB : ELEMENT-FORCE GRADIENT (dFe/db)

```
=======================================================================
=  Element    Design     Vector             dFe/db                    =
=  Number     Variable   Length     ------------------------          =
=             Number                                                  =
=......................................................................
=   I           I          I          RVEC                            =
=======================================================================
=                                                                     =
=                                                                     =
=                                                                     =
=                                                                     =
=                                                                     =
=                                                                     =
=======================================================================
```

SDSFDB : SUBSTRUCTURE-ELEMENT-FORCE GRADIENT (dF_e/db)

```
======================================================================
= Substr.   Element  Design   Vector            dFe/db               =
= Number    Number   Variable         -----------------------------  =
=                    Number   Length                                 =
=....................................................................=
=   I          I        I        I          RVEC                     =
======================================================================
=                                                                    =
=                                                                    =
=                                                                    =
=                                                                    =
=                                                                    =
=                                                                    =
======================================================================
```

SDFEDZ : ELEMENT-FORCE GRADIENT (dF_e/dz)

```
======================================================================
=  Element  Global      Vector          dFe/dz Coefficients          =
=  Number   Equation              ----------------------------       =
=           Number      Length                                       =
=                                                                    =
=....................................................................=
=    I         I           I          RVEC                           =
======================================================================
=                                                                    =
=                                                                    =
=                                                                    =
=                                                                    =
=                                                                    =
=                                                                    =
======================================================================
```

SDZIDB : SUBSTRUCTURE-DZIDB MATRIX (dZ_i/db for Ith Substructure)

```
======================================================================
= Substructure Reused Loading    Substr.  Time   dZi/db Coefficients =
=  Number      Substr.Condition  Equation        ---------------------=
=              No.    Number     Number           1  2  3  . No. of D.V.=
=                                                in this Substructure =
=....................................................................=
=    I          I       I        I        R       RVEC               =
======================================================================
=                                                                    =
=                                                                    =
=                                                                    =
=                                                                    =
=                                                                    =
=                                                                    =
======================================================================
```

SDZBDB : SUBSTRUCTURE-DZIDB MATRIX (dZ_b/db for Ith Substructure)

```
=======================================================================
= Substructure Reused Loading    Substr.  Time   dZb/db Coefficients  =
=  Number      Substr.Condition  Equation        ---------------------=
=              No.    Number     Number          1  2  3  .  No. of D.V.=
=                                                in this Substructure  =
=.....................................................................=
=    I          I       I        I         R      RVEC                 =
=======================================================================
=                                                                     =
=                                                                     =
=                                                                     =
=                                                                     =
=                                                                     =
=                                                                     =
=======================================================================
```

SDZZDB : GLOBAL-DZBDB MATRIX (dZ/db)

```
=======================================================================
=  Loading          Global   Time          dZ/db  Coefficients          =
=  Condition        Equation         -------------------------------=
=  Number           Number           1  2  3  .  .  No. of D.V.       =
=.....................................................................=
=    I                I        R         RVEC                          =
=======================================================================
=                                                                     =
=                                                                     =
=                                                                     =
=                                                                     =
=                                                                     =
=                                                                     =
=======================================================================
```

SDALDB : Augmented Lagrangian Gradient

```
========================================================================
= Design Variable No.   Augmented Lagrangian Gradient Vector          =
=                       ----------------------------------------      =
=                         Previous Value       Current Value          =
=-------------------------------------------------------------        =
=        I                    R                    R                  =
========================================================================
=                                                                      =
=                                                                      =
=                                                                      =
=                                                                      =
=                                                                      =
=                                                                      =
========================================================================
```

SDALBZ : Response Derivatives of Augmented Lagrangian

Equation Number	Response Derivatives of Augmented Lagrangian	
	at $t=t_j$	at $t=T-t_j$
I	R	R

SFBGRD : EFFECTIVE-FORCE GRADIENTS (C^* - MATRIX)

Global Equation Number	Loading Condition	C^* - Matrix Coefficients
		1 2 3 . . No. of Design Var.
I	I	RVEC

SDFBDB : SUBATRUCTURE-EFFECTIVE-BOUNDARY-FORCE GRADIENT (C1 - MATRIX)

Substr. Number	Reused Substr. Number	Substr. Equation Number	Load Case Number	C_1 - Matrix Coefficients
				1 2 3 . No. of Design Var. in this Substructure
I	I	I	I	RVEC

SFIGRD : SUBSTRUCTURE-INTERNAL-FORCE GRADIENT (C_2 - MATRIX)

```
========================================================================
=  Substr. Reused   Substr.  Loading     C2 - Matrix Coefficients      =
=          Substr.  D.O.F.   Condition -------------------------       =
=  Number  Number   Number              1  2  3  . No. of Design Var.  =
=                                       in this Substructure           =
=......................................................................=
=     I        I        I                RVEC                          =
========================================================================
=                                                                      =
=                                                                      =
=                                                                      =
=                                                                      =
=                                                                      =
=                                                                      =
========================================================================
```

SADJII : SUBSTRUCTURE-LAMDAI MATRIX (λ_I)

```
========================================================================
=  Substr Reused  Constraint  Time           Adjoint Variables         =
=  No.    Substr.  Number           ----------------------------------=
=         No.                       1  2  3   .  No. of internal DOF  =
=......................................................................=
=    I      I        I        R           RVEC                         =
========================================================================
=                                                                      =
=                                                                      =
=                                                                      =
=                                                                      =
=                                                                      =
=                                                                      =
========================================================================
```

SADJBB : SUBSTRUCTURE-LAMDAB MATRIX (λ_B)

```
========================================================================
=  Substr Reused  Constraint  Time           Adjoint Variables         =
=  No.    Substr.  Number          -----------------------------------=
=         No.                     1  2  3   .  No. of Boundary DOF  =
=......................................................................=
=    I      I        I         R          RVEC                         =
========================================================================
=                                                                      =
=                                                                      =
=                                                                      =
=                                                                      =
=                                                                      =
=                                                                      =
========================================================================
```

SADJNB : LAMDAB MATRIX (ADJOINT VARIABLES FOR GLOBAL DOF) (λ_B)

```
==========================================================================
=  Constraint  Time         Adjoint Variables                            =
=  Number                ---------------------------------------------   =
=  (Active)               1    2    3    .    .    .   No. of DOF(Global) =
=.........................................................................=
=        I       R                 RVEC                                  =
==========================================================================
=                                                                        =
=                                                                        =
=                                                                        =
=                                                                        =
=                                                                        =
=                                                                        =
==========================================================================
```

SADJAL : ADJOINT VARIABLES FOR AUGMENTED LAGRANGIAN GRADIENT

```
===========================================================================
= Time     Time                        Adjoint Variables                  =
= Step     Value            -----------------------------------------     =
=                           1 2 3 . . . .        NDOF (No. of DOF)        =
= ----------------------------------------------------------------------- =
=  I        I                            RVEC                             =
===========================================================================
=                                                                         =
=                                                                         =
=                                                                         =
=                                                                         =
=                                                                         =
=                                                                         =
===========================================================================
```

SDAWDB : DIFFERENTIAL-ALLOWABLE-STRESS

```
==========================================================================
=  Element    Design    Vector       dσ/ab                               =
=  Number     Variable            -----------------                      =
=             Number    Length    dF_bx/db,dF_by/db,dF_ex/db,.......(BEAM) =
=                                 dF_a/db                          (TRUSS)=
=                         NL      (ALWSGR(I),I=1,NL)                     =
=.........................................................................=
=     I            I        I       RVEC                                 =
==========================================================================
=                                                                        =
=                                                                        =
=                                                                        =
=                                                                        =
=                                                                        =
=                                                                        =
==========================================================================
```

SDSWDB : SUBSTRUCTURE-DIFFERENTIAL-ALLOWABLE-STRESS

```
=====================================================================
= Substr. Element Design   Vector      dσ/db                        =
= Number  Number  Variable          ----------------                =
=                 Number   Length   dF_bx/db,dF_by/db,.....(BEAM)   =
=                                   dF_a/db               (TRUSS)   =
=                            NL     (ALWSGR(I),I=1,NL)              =
=...................................................................=
=    I       I       I       I          RVEC                        =
=====================================================================
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
=====================================================================
```

SDGVDB : DIFFERENTIAL-EIGENVECTOR MATRIX

```
=====================================================================
= Damaged    Mode    Global                  dy/db                  =
= Condition          Equation   ---------------------------         =
= Number     Number  Number                                         =
=                               1   2   3   .   No. of Design Var.  =
=...................................................................=
=    I         I       I                RVEC                        =
=====================================================================
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
=====================================================================
```

SDKGDB : DIFFERENTIAL-ELEMENT-GEOMETRIC STIFFNESS MATRIX (dK_g/db)
(DERIVATIVE OF ELEMENT GEOMETRIC STIFFNESS MATRICES w.r.t.D.V.)

```
=====================================================================
= Element       Design       Matrix Size      dK_g/db Coefficients  =
= Variable                                                          =
= Number        Number                                              =
=...................................................................=
=           I         I        I                DMAT                =
=====================================================================
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
=                                                                   =
=====================================================================
```

SDKGDZ : DIFFERENTIAL-ELEMENT-GEOMETRIC STIFFNESS MATRIX (dK_g/dz) (DERIVATIVE OF ELEMENT GEOMETRIC STIFFNESS MATRICES w.r.t. STATE.V.)

```
======================================================================
= Element      Global      Matrix Size     dKg/db Coefficients       =
=              Equation                                              =
= Numbe        Number                                                =
=...................................................................=
=           I          I        I                 DMAT               =
======================================================================
=                                                                    =
=                                                                    =
=                                                                    =
=                                                                    =
=                                                                    =
=                                                                    =
======================================================================
```

SNSTVY : SENSITIVITY MATRIX

```
======================================================================
=  Constraint Hyper Matrix        Sensitivity Coefficients           =
=  Number     -------------    -----------------------------         =
=  (Active) Col No. Row No.      1   2    3  .  No of Design Var.    =
=...................................................................=
=     I                                          RVEC                =
======================================================================
=                                                                    =
=                                                                    =
=                                                                    =
=                                                                    =
=                                                                    =
=                                                                    =
======================================================================
```

SHESMT: Hessian Matrix of Augmented Lagrangian

```
==================================================================
= Iteration Number  Hyper-       Null Index  Hessian Submatrix   =
=                                                                =
=                   Row  Column                                  =
= ------------------------------------------------------------- =
=      I            I      I        I               DMAT         =
==================================================================
=                                                                =
=                                                                =
=                                                                =
=                                                                =
=                                                                =
=                                                                =
==================================================================
```

IDGNVB : DESIGN VARIABLES

```
=======================================================================
= D. V.  Current   Current Value  Upper Bound Lower Bound Status      =
= Number Design                                           Fixed/Free  =
=        Change                                                       =
=.....................................................................=
=   I                  R                R         R          I        =
=======================================================================
=                                                                     =
=                                                                     =
=                                                                     =
=                                                                     =
=                                                                     =
=                                                                     =
=======================================================================
```

ISDGIF : SUBSTRUCTURE-DESIGN-VARIABLE-GROUP INFORMATION

```
=======================================================================
= Substr.      Number of       Status    Design Variable Group        =
=              Design                           Number                =
= Number       Variable Group          -----------------------------  =
=.....................................................................=
=   I             I              I           IVEC                     =
=======================================================================
=                                                                     =
=                                                                     =
=                                                                     =
=                                                                     =
=                                                                     =
=                                                                     =
=======================================================================
```

IDVGIF : DESIGN-VARIABLE-GROUP INFORMATION

```
=======================================================================
=  Design Variable      Number of         Design Variable Number      =
=  Group                Design        ----------------------------    =
=  Number               Variable                                      =
=.....................................................................=
=   I                     I                 IVEC                      =
=======================================================================
=                                                                     =
=                                                                     =
=                                                                     =
=                                                                     =
=                                                                     =
=                                                                     =
=======================================================================
```

IDSHIS : DESIGN HISTORY

```
======================================================================
=   Iteration   Cost      Convergent Max.                            =
=               Function             Constraint                      =
=   Number      Value     Parameter  Violation                       =
=                                                                    =
=....................................................................=
=     I           R          R           R                           =
======================================================================
=                                                                    =
=                                                                    =
=                                                                    =
=                                                                    =
=                                                                    =
=                                                                    =
======================================================================
```

IDVHIS : DESIGN VARIABLE HISTORY

```
======================================================================
= Iteration               Design Value for Each D.V Number           =
= Number          -------------------------------------------------- =
=                         1 2 3   ............No of D.V              =
=....................................................................=
=    I               RVEC                                            =
======================================================================
=                                                                    =
=                                                                    =
=                                                                    =
=                                                                    =
=                                                                    =
=                                                                    =
======================================================================
```

ICNHIS : CONSTRAINT VIOLATION HISTORY

```
======================================================================
= Iteration               Constraint Function Value                  =
= Number          -------------------------------------------------- =
=                 1 2 3   ............No of constraint No.           =
=....................................................................=
=    I               RVEC                                            =
======================================================================
=                                                                    =
=                                                                    =
=                                                                    =
=                                                                    =
=                                                                    =
=                                                                    =
======================================================================
```

IHISTA : HISTORY OF AUGMENTNED LAGRANGIAN

```
==========================================================================
=   Iteration          Number of            Augmented Lagrangian         =
=    Number        Active Constraints            History                 =
=                                                                        =
= ---------------------------------------------------------------------- =
=      I                    I                        R                   =
==========================================================================
=                                                                        =
=                                                                        =
=                                                                        =
=                                                                        =
=                                                                        =
=                                                                        =
==========================================================================
```

6.5 DATABASE STRUCTURE

In this section data sets are grouped into seven databases. The classification of the databse is made based on type of analysis and design optimization. The names and contents of these databases are as follows:

1) General data sets : GDASET
2) Linear static analysis : LISANS
3) Linear dynamic analysis : LIDANS
4) Nonlinear static analysis : NLSANS
5) Nonlinear dynamic analysis : NLDANS
6) Linear optimization (static/dynamic) : LINOPT
7) Nonlinear optimization (static/dynamic): NLIOPT

List of data sets for each of the databases is given as follows:

GDASET :

ABCIIC : Bounadry condition and intial condition information
ACOMPR : Composite-element properties (layered)
ACORDC : Node-coordinate for master structure
ACORDS : Node-coordinate for subsrtucture(s)
ADYNLD : Dynamic load definition
AELCON : Element-connectivity
AELGNI : Element general information
AELHYP : Equation numbers contributing to a hypermatrix
AELLOD : Element-load data for master structure
AELPRO : Element-properties
AELTRF : Element-transformation matrix
AFOREL : Element nodal force vector
AINLOD : Inertia node-load
AISREL : Initial strain vector (element)
AISTEL : Initial stress vector (element)
AMATPR : Related linear material properties
AMIDS : Mid-surface normal vector information
ANODDF : Node-dof global structure

ANODLD : Equivalent node-load data for the master structure
ANODTM : Node-temperature
ANONMT1: Nonlinear material type 1
ASELLOD: Element-load data for substructure(s)
ASETRM : Substructure element-transformation matrix
ASFOEL : Substructure element nodal force vector
ASKEW : Skew coordinate system defintion
ASUBDF : Node-dof substructure(s)
ASUBGI : Substructural genreal information
CDSIIF : Design-optimization-integer-control information
CDSRIF : Design-optimization-real-control information
CINTCL : Integer control information
CREAL : Real control information
CTITLE : Title of the problem
DACNIF : Constraint information
DALWST : Element -allowable-stresses
DDSPLT : Displacement-limits
DFRQLT : Frequency limits
IDGNVB : Design variables
IDVGIF : Design-variable-group information
ISDGIF : Substructure-design-variable-group information

LISANS:

AAGLMT : Assembled load matrix (global) for linear statics
AALBMT : Substructure load matrix (boundary)
ADISPLG: Displacement matrix (global)
ADLSMT : Decomposed linear stiffness matrix (global)
AELMAT : Element-stiffness matrix (linear)
ASCLMT : Condensed load matrix (substructure) for linear statics
ASDISB : Substructure displacement matrix (boundary)
ASDISI : Substructure displacement matrix (internal)
ASESMT : Substructure element-stiffness matrix (linear)
ASLIMT : Substructure load matrix (internal)
ASLOMB : Substructure load matrix (boundary) for linear statics
ASLOMI : Substructure load matrix (internal) for linear statics
ASLSMT : Assembled linear stiffness matrix (global)
ASNOLD : Equivalent node-load data for substructure(s)
ASSBBN : Assembled substructure stiffness matrix (boundary)
ASSBIB : Assembled substructure stiffness matrix (internal-boundary)
ASSBIN : Assembled substructure stiffness matrix (internal)
ASSTAL : Substructure strain vector (element)
ASSTEL : Substructure stress vector (element)

LIDANS:

AASIDN : Acceleration vector (global) for dynamics/nonlinear
ACLDMT : Condensed load matrix for linear dynamics/nonlinear statics
ACODCM : Node-damping and mass matrix
ACSDMT : Condensed substructure damping matrix
ACSSMT : Condensed substructure mass matrix
ADESMT : Decomposed effective linear stiffness matrix (global-dynamics)
ADGIDN : Displacement matrix (global) for linear/nonlinear dynamics

ADSIDN : Displacement matrix (internal) for dynamics
ADSSMT : Decomposed effective substructure stiffness matrix
AEGVEC : Eigenvalues and eigenvectors
AELDMT : Effective substructure load matrix for linear dynamics
AELMAS : Element-mass matrix (lumped/diagonal)
AELMAT : Element-stiffness matrix (linear)
AELMSC : Element-mass matrix (consistent)
AELSMT : Effective linear stiffness matrix (global-dynamics)
AESSMT : Effective substructure stiffness matrix (dynamics)
AGELMT : Global effective load matrix for linear/nonlinear dynamics
AGESMT : Generalized structural matrices for modal analysis
AGLDMT : Global load matrix for linear/nonlinear dynamics
AMASHY : Assembled substructure mass matrices (internal)
ASABDN : Substructure acceleration vector (boundary)
ASAIDN : Substructure acceleration vector (internal)
ASDMAT : Substructure damping matrix (internal)
ASDMTB : Substructure damping matrix (boundary)
ASELMS : Substructure element-mass matrix (lumped/diagonal)
ASEMMC : Substructure element-mass matrix (consistent)
ASLDMT : Assembled damping matrix (global)
ASLMMT : Assembled mass matrix (global)
ASLSMT : Assembled linear stiffness matrix (global)
ASMBON : Assembled substructure mass matrices (boundary)
ASMINB : Assembled substructure mass matrices (internal-boundary)
ASSBBN : Assembled substructure stiffness matrix (boundary)
ASSBIB : Assembled substructure stiffness matrix (internal-boundary)
ASSBIN : Assembled substructure stiffness matrix (internal)
ASTRAL : Strain vector (element)
ASTREL : Stress vector (element)
ASVIDN : Substructure velocity vector (internal)
AVELDN : Velocity vector (global)

NLSANS:

ABUCEL : Buckling load factor and mode shape
ACLDMT : Condensed load matrix for linear dynamics/nonlinear statics
AFTGSM : Final tangential global stiffness matrix
ANSTMT : Assembled nonlinear stiffness matrix
ASTNEL : Element stiffness matrix (nonlinear)

NLDANS:

AASIDN : Acceleration vector (global) for dynamics/nonlinear
ADFTES : Decomposed final tangential effective stiffness matrix
ADFTGS : Decomposed final tangential global stiffness matrix
ADGIDN : Displacement matrix (global) for linear/nonlinear dynamics
AELMAS : Element-mass matrix (lumped/diagonal)
AELMSC : Element-mass matrix (consistent)
AFTESM : Final tangential effective stiffness matrix
AFTGSM : Final tangential global stiffness matrix
AGLDMT : Global load matrix for linear/nonlinear dynamics
ANSTMT : Assembled nonlinear stiffness matrix
ASLDMT : Assembled damping matrix (global)
ASLMMT : Assembled mass matrix (global)

ASTNEL : Element stiffness matrix (nonlinear)
ASTRAL : Strain vector (element)
ASTREL : Stress vector (element)
AVELDN : Velocity vector (global)
CLGPNA : Lagrange multipliers and penalty parameters

LINOPT:

ICNHIS : Constraint violation history
IDSHIS : Design history
IDVHIS : Design variable history
IHISTA : History of augmented lagrangian
SADJAL : Adjoint variables for augmented lagrangian gradient
SADJBB : Substructure-lamdab matrix (λ_B)
SADJII : Substructure-lamdai matrix (λ_I)
SADJNB : Lamdab matrix (adjoint variables for global dof) (λ_B)
SCNSGD : Constraint-gradient
SCSTGD : Cost-gradient
SDALBZ : Response derivatives of augmented lagrangian
SDALDB : Augmented lagrangian gradient
SDAWDB : Differential-allowable-stress
SDCBDZ : Substructure-boundary-constraint-gradient
SDCEDB : Differential-element-damping matrix (dC/db)
SDCIDZ : Substructure-internal-constraint-gradient
SDEGDB : Differential-element-stress matrix
SDFBDB : Substructure-effective-boundary-force gradient (C_1 - matrix)
SDFEDB : Element-force gradient (dFe/db)
SDGVDB : Differential-eigenvector matrix
SDKKDB : Substructure-differential-element-stiffness matrix (dKs/db)
SDKSDB : Differential-element-stiffness matrix (dKs/db)
SDMCDB : Differential-element-mass matrix (dMc/db)
SDMDDB : Differential-element-mass matrix (dMd/db)
SDSCDB : Substructure-differential-element-mass matrix (dMc/db)
SDSDDB : Substructure-differential-element-mass matrix (dMd/db)
SDSFDB : Substructure-element-force gradient (dFe/db)
SDSGDB : Substrructure-differential-element-stress matrix
SDSWDB : Substructure-differential-allowable-stress
SDZBDB : Substructure-dZbdb matrix (dZ_b/db for ith substructure)
SDZIDB : Substructure-dZidb matrix (dZ_i/db for ith substructure)
SDZZDB : Global-dzbdb matrix (dz/db)
SFBGRD : Effective-force gradients (C - matrix)
SFIGRD : Substructure-internal-force gradient (C_2 - matrix)
SHESMT : Hessian matrix of augmented lagrangian
SNSTVY : Sensitivity matrix
SSCDB : Substructure-differential-element-damping matrix (dC/db)

NLIOPT:

ICNHIS : Constraint violation history
IDSHIS : Design history
IDVHIS : Design variable history
IHISTA : History of augmented lagrangian
SADJAL : Adjoint variables for augmented lagrangian gradient

SADJNB : Lamdab matrix (adjoint variables for global dof) (λ_B)

SCNSGD : Constraint-gradient

SCSTGD : Cost-gradient

SDALBZ : Response derivatives of augmented lagrangian

SDALDB : Augmented lagrangian gradient

SDAWDB : Differential-allowable-stress

SDCEDB : Differential-element-damping matrix (dV/db)

SDDCDZ : Differential-constitutive matrix (material nonlinear)

SDEGDB : Differential-element-stress matrix

SDEGDZ : Differential-element-stress matrix ($d\sigma/dz$)

SDFEDB : Element-force gradient (dFe/db)

SDFEDZ : Element-force gradient (dFe/dz)

SDKGDB : Differential-element-geometric stiffness matrix (dKg/db)

SDKGDZ : Differential-element-geometric stiffness matrix (dKg/dz)

SDKSDB : Differential-element-stiffness matrix (dKs/db)

SDKSDZ : Differential-element-stiffness matrix (dKs/dz)

SDMCDB : Differential-element-mass matrix (dMc/db)

SDMCDZ : Differential-element-mass matrix (dMc/dz)

SDMDDB : Differential-element-mass matrix (dMd/db)

SDMDDZ : Differential-element-mass matrix (dMd/dz)

SDSBDZ : Differential-element-strain-displacement matrix (dB/dz)

SDZZDB : Global-dzbdb matrix (dz/db)

SFBGRD : Effective-force gradients C - matrix)

SHESMT : Hessian matrix of augmented lagrangian

SNSTVY : Sensitivity matrix

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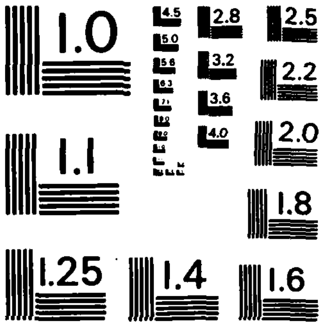

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7. IMPLEMENTATION OF A DATABASE MANAGEMENT SYSTEM -- MIDAS

7.1 INTRODUCTORY REMARKS

A database management system - MIDAS* has been implemented for finite element analysis and structural design optimization applications. The MIDAS implementation is based on the requirements of a database given in Chapter 2. MIDAS has two subsystems - MIDAS/R and MIDAS/N. These subsystems are capable of organizing data of relational and numerical models, respectively. The system has been installed on PRIME computer system. It relieves the burden of managing data for application programmers by providing user-friendly application commands. The system has sophisticated interactive commands to query the database. The MIDAS system can be used either interactively or through application programs. The implementation details of MIDAS/R and MIDAS/N are given in Sections 7.2 and 7.3, respectively.

7.2 IMPLEMENTATION OF MIDAS/R

In this section, capabilities, database organization, data definition, data manipulation and query commands of MIDAS/R are described. Also, details of the system architecture are given. MIDAS/R database management system is based on relational data model. The system is developed by modifying and extending the RIM program (Relational Information Management System).

7.2.1 Capabilities of MIDAS/R

MIDAS/R is written in FORTRAN-77. The system does not have any machine dependent instructions and therefore it is highly portable. It has data definition and data manipulation commands which are simple to use for application programmers. It has sophisticated interactive commands to query the database, modify the database and display the database schema. The system has capability to store, retrieve, modify and delete a database using both application call statements and interactive commands. The data can be integer, real, double-precision and character words. The data can be organized in the form of relations. The system has powerful relational algebra commands like SELECT, PROJECT and JOIN. MIDAS/R has capability to provide access to the database simultaneously for multiple users. Database security is provided through two level password system. Error recovery mechanisms are available.

7.2.2 Database of MIDAS/R

MIDAS/R has capability to create a number of databases. The databases can be used one at a time. The database can be either permanent or temporary. The size of a database is unlimited but depends only on the availability of disk space. Database of MIDAS/R can hold any number of relations each of which is identified by a unique name. A relation can store

*(Management of Information for Design and Analysis of Systems)

data of a number of attributes. An attribute value can be a single data item, a vector or a matrix. Variable length rows of a relation can be stored.

7.2.3 Data Definition Commands of MIDAS/R

Data definition commands are used in an application program to define a database, relations and attributes. These commands are FORTRAN subroutine call statements. These commands were not available in RIM program. The data definition commands of MIDAS/R are described in the following paragraphs.

Database Initialization:

CALL RDBINT

This command initializes MIDAS/R. Before using any other commands of the system, this command must be used.

Database Definition:

CALL RDBDFN (NAME, STAT, IERR)

NAME = Name of the database

STAT = Permanent or temporary status of the database

IERR = Error Code

A unique database can be defined using this command. A temporary database is deleted when it is closed.

Relation Definition:

CALL RELDFN (NAME, RNAME, NCOL, CNAME, CTYPE, IELM, JELM, KEY, IERR)

NAME = Name of the database

RNAME = Relation name

NCOL = Number of attribute columns

CNAME = A vector of attribute names

CTYPE = A vector of attribute type

IELM = A vector of row size of attributes

JELM = A vector of column size of attributes

KEY = A vector of key attribute indicator

IERR Error code

A relation can be defined using this command. Relation name and attribute names must be unique in a database. A row and column intersection in a relation table can contain either a single data item, a vector or a matrix. Details of data type and layout of data in a typical relation are given in Figures 7.2.1 and 7.2.2, respectively.

Data Set Definition:

```
CALL RDSDFN (NAME, DSNAME, DTYPE, IELM, JELM, IERR)

    NAME    = Name of the database

    DSNAME  = Name of the data set

    DTYPE   = Data type (see Figure 7.2.1)

    IELM    = Row size of a attribute (see Figure 7.2.1)

    JELM    = Column size of a attribute (see Figure 7.2.1)

    IERR    = Error code
```

A data set is defined as a collection of data belonging to same data type such as single data item, vector, or matrix. In a sense, a data set is a relation having only one attribute. Name of data set has to be unique in a database.

Data Set Redefinition:

```
CALL RDRDFN (NAME, DSNAME, DTYPE, IELM, JELM, IERR)
```

Arguments are same as in data set definition. This command redefines a data set using new data type, and new attribute size. Old data set definition and its data is lost.

Data Definition Ending:

```
CALL RDSEND (IERR)

    IERR = Error Code
```

After database, relations and data sets have been defined, data definition process is ended by calling this routine. During execution of this call statement, the data definition is verified and compiled internally.

7.2.4 Data Manipulation Commands MIDAS/R

Data manipulation commands open, close, store, retrieve, modify, and delete data, rename a relation or a data set, rename an attribute and copy data sets in a database. These commands were not available in the RIM program. The function and description of these commands are given in the following paragraphs.

Description	TYPE	IELM	JELM
Integer	INT	1	1
Real	REAL	1	1
Double Precision	DOUB	1	1
Integer Vector	IVEC	n	1
Real Vector	RVEC	n	1
Double Precision Vector	DVEC	n	1
Integer Matrix	IMAT	m	n
Real Matrix	RMAT	m	n
Double Precision Matrix	DMAT	m	n
Text or Character	TEXT	n	1

NOTE: Values of IELM and JELM if 0 indicate that data is of variable length.

Figure 7.2.1 Data Type and Size of a Relation

Attribute A	Attribute B	Attribute C	Attribute D
Key	Type INT	IVEC	IMAT
1	x	x x x x	x x x x
			x x x x
			x x x x
			x x x x
2	x	x x x x	x x x x
			x x x x
			x x x x
			x x x x
..	..	..	..
r	x	x x x x	x x x x
			x x x x
			x x x x
			x x x x

NOTE: For Attribute A IELM = 1, JELM = 1
Attribute B IELM = 1, JELM = 4
Attribute C IELM = 4, JELM = 4

Figure 7.2.2 Layout of Data in a Typical Relation

Open a Database:

```
CALL RDBOPN (NAME, STAT, IERR)

    NAME   = Name of the database

    STAT   = Permanent or temporary status of the database

    IERR   = Error code
```

A database closed earlier can be opened using this command. A database has to be opened before any operation on the database is performed.

Close a Database:

```
CALL RDBEND (IERR)

    IERR   = Error code
```

A database is closed using this command. Execution of this command transfers the system buffer data into the database and closes the file.

Store Data in a Relation:

```
CALL RDSPUT (NAME, DSNAME, KROW, UBUF, IERR)

    NAME   = Name of the database

    DSNAME = Name of a relation

    KROW   = Row number

    UBUF   = User buffer which contain data

    IERR   = Error code
```

Data can be stored into a relation from application program work area (user buffer) by using this command. Data is transfered from user buffer to the specified row of a relation. If more rows have to be stored, a FORTRAN DO loop over the row number in the application program will transfer all the required rows. More details of this command are given in the user's manual (Sreekanta Murthy and Arora, 1984).

Retrieve Data from a Relation:

```
CALL RDSGET (NAME, DSNAME, KROW, UBUF, IERR)
```

Data can be retrieved from a relation into a user buffer using this command. Requested row of a relation is transfered from a relation into user buffer. FORTRAN DO loop over the row number is necessary if more than one row has to be retrieved. Data can be retrieved in the same order as it was stored by initializing row number as zero. Data of a relation satisfing certain condition (for example, attributes having certain values) can be retrieved into user buffer. User specifies the condition on data values that must be satisfied for retrieval, by using RDSRUL command (explained later). The details for various ways of data retrieval is given in the user's manual (Sreekanta Murthy and Arora, 1984). Arguments are the same as in RDSPUT.

Modify Data in a Relation:

```
CALL RDSMOD (NAME, DSNAME, KROW, UBUF, IERR)
```

Once a database is loaded using RDSPUT command, it can be modified by calling RDSMOD. This routine modifies a row of the relation. RDSGET routine is called before calling this subroutine. A row of a relation is retrieved into user buffer and this row or a part of the row can be modified and stored back using the command. Arguments are the same as in RDSPUT.

Delete Rows of a Relation:

```
CALL RRWDEL (NAME, DSNAME, KROW, IERR)
```

Rows of a relation can be deleted using this command. This is useful in eliminating unwanted values in a relation. Arguments are the same as in RDSPUT.

Delete a Relation:

```
CALL RDSDEL (NAME, DSNAME, IERR)
```

This command deletes a relation from a database. Arguments are the same as in RDSPUT.

Rename a Relation:

```
CALL RDRNAM (NAME, OLDNAM, NEWNAM, IERR)
```

NAME	=	Name of a database
OLDNAM	=	Old name of the relation
NEWNAM	=	New name of the relation
IERR	=	Error code

An existing relation's name can be changed to a new name using the command.

Rename an Attribute:

```
CALL RRNATT (NAME, DSNAME, OLDATT, NEWATT, IERR)
```

NAME	=	Name of a database
DSNAME	=	Relation name
OLDATT	=	Old attribute name

NEWATT = New attribute name

IERR = Error code

Copy a Relation:

CALL RDSCPY (NAME1, NAME2, DSNAM1, DSNAM2, IERR)

NAME1 = Name of a database containing data

NAME2 = Name of a database where data has to be copied

DSNAM1 = Relation name containing data

DSNAM2 = Relation name to where data has to be copied

IERR = Error code

Using this command, data from one relation can be copied to another relation. Both the database and relation must have been defined before copying the data.

Condition Specification for Retrieval of Data:

CALL RDSRUL (NUM, ATNAM, COND, VALUE, BOOL, IERR)

NUM = Number of conditions

ATNAM = A vector of attribute names

COND = A vector of logical operator (EQ, GT, LT)

VALUE = A vector of attribute values

BOOL = A vector of Boolean operator (AND,OR)

IERR = Error code

As mentioned in RDSGET command, data values satisfying certain conditions can be retrieved. The conditions can be specified using RDSRUL command. This command must be executed before calling RDSGET routine. A maximum of ten conditions can be specified at a time. The following example, illustrates use of this command.

Condition on a relation X:

Attribute A•GT•15•3 •AND• Attribute B•LT•20•1

```
Use NUM = 2; ATNAM(1) = 'A'; ATNAM(2) = 'B'
    COND(1) = 'GT'; COND(2) = 'LT';
    VALUE(1) = 15.3; VALUE(2) = 20.1;
    BOOL(1) = 'AND'
```

7.2.5 Interactive Commands

MIDAS/R provides interactive support for creating, updating, modifying, and deleting a database. Interactive commands are general and can be used in any application. The system provides terminal prompts for the users to respond with appropriate commands. The interactive session starts with a display of MENU and requests the user to choose one of the five options: CREATE, UPDATE, QUERY, COMMAND and EXIT. The interactive session ends with an EXIT command. The detailed commands for each of these options are entered at appropriate instant. They are given in the following paragraphs.

Database Definition:

```
CREATE XXXX
```

Create command branches out to interactively define a new database. System responds by requesting database, relation and attribute names, and authorization access details. User can supply these data at the prompt. Details of using this command are given in user's manual (Sreekanta Murthy and Arora, 1984).

Loading a Database:

After a database has been successfully created, it may be loaded before ending 'create' session. for user response 'Y' for the load prompt, the list of existing relations that may be loaded are displayed. The values of attributes are entered corresponding to each attribute type.

Querying a Database:

A database defined and loaded as specified in the previous paragraphs can be queried. Query will be in the COMMAND mode of interactive session. There are a number of query commands which allow users to query a database. They are described in the following paragraphs.

1. SELECT

Select command is used for displaying data of a relation. Options to display all or selected attributes are available. Several possible select options are given below:

```
SELECT ALL FROM [relation name]

SELECT [attribute name] FROM [relation name]

SELECT ALL FROM [relation name] WHERE [attribute name] [condition]
    [values] [AND/OR] ...
```

continuation dots indicate that upto ten conditions can be specified. The conditions have to the one of the following

```
(a) [attribute name] [EQ|NE|GT|LT|LE|GE] [value]

(b) [attribute name] [EQ|NE|GT|LT|LE|GE| [attribute name]

(c) ROWS [EQ|NE|LT|LE|GE] [row number]
```

2. LISTREL

List command allows user to display information about relations and attributes. The following options are available in LISTREL command.

```
LISTREL

LISTREL [relation name]

LISTREL ALL
```

3. CHANGE

Data values in a relation can be changed using this command. The following options are available

```
CHANGE [attribute] TO [value] IN [relation name]

CHANGE [attribute] TO [VALUE] IN [relation name]
    WHERE ...
```

4. DELETE

This command can be used to delete selected rows in a relation:

```
DELETE ROWS FROM  [relation name] WHERE ...
```

5. RENAME

Attributes and relations can be renamed using this command:

```
RENAME [attribute] TO [attribute] In [relation name]

RENAME RELATION [relation name] TO [relation name]
```

6. REMOVE

A relation can be deleted from database definition using REMOVE command:

```
REMOVE [relation name]
```

7. PROJECT

This is a relational algebra command. The function of PROJECT is to create a new relation as a subset of an existing relation. The new relation is created from an existing relation by removing attribues, rows or both.

```
PROJECT [relation name] FROM [relation name]

USING [attribute] [ attribute] ... WHERE ...
```

8. JOIN

The purpose of JOIN command is to combine two relations based on specific attributes from each row. The result of JOIN command is a third relation containing all the specified attributes from both the relations.

```
JOIN [relation name] USING [attribute name]

WITH [relation name] USING [attribute name]

FORMING [relation name] WHERE ...
```

9. INPUT

This command assigns input file for MIDAS/R to read data without user interaction

```
INPUT [file name]
```

10. OUTPUT

The output of execution may be placed in a given file name. If file name is TERMINAL, then all messages and data are displayed at the terminal:

```
OUTPUT [file name]
```

11. EXIT/QUIT

The system buffer data is transfered to database files and database is closed.

12. HELP

User can obtain a description of the available commands on the terminal.

7.2.6 Program Details

MIDAS/R program has about 390 subroutines, 40,000 FORTRAN source statements, and 38 common blocks. Subroutines can be grouped into (i) initialization routines, (ii) file definition routines, (iii) input-output routines, (iv) addressing and searching routines, (v) integrity rule processing routine, (vi) memory management routines, (vii) command processing routine, (viii) relational algebra routines, and (ix) security and protection routines. A brief description of these routines is given in the following paragraphs.

Initialization routines, initialize integer, real and double precision variables. Hollerith constants are assigned to variables. Also, they initialize various common blocks and system bufier arrays. Important initialization routines are RMSTRT, BLKCLN, ZEROIT, RMCONS, and LXCONS.

File definition routines are RMOPEN, RMCLOS, F1OPN, F2OPN, F3OPN, F1CLO, F2CLO, F3CLO, RIOOPN, SETIN, and SETOUT. Each database in MIDAS/R has three files. The first file contains data definition details of relations and attributes. The second file contains actual data. The third file contains keys for locating data. File definition routines open and close database files, assign a database to a logical unit, and assign input and output files.

Input-output routines carryout operations for storing and retrieving data. The main routines for storing and retrieving data are RMPUT and RMGET. They inturn call routines GETDAT and PUTDAT. These routines perform data transfer operations between system buffer and user buffer. At the lowest level, RIOIN and RIOOUT routines actually read and write data in database files. RELGET, RELPUT, RELDEL, and RELADD routines, respectively, get a table from a relation, replace current table from a relation table, delete a current table in a relation table, and add a new tuple to the relation table. Similarly, ATTGET, ATTPUT, ATTDEL and ATTADD routines operate on an attribute table.

Addressing and searching routines determine the physical storage address of data. Relations are stored in random access files. The location of a relation in the data file is specified by a index table. Indicies are assigned to relations by HTOI and IOTH routines. Searching of these indices is done by using binary tree lookup. BTADD, BTGET, BTPUT and BTREP routines add, retrieve, put and replace values in a binary tree. A call to RMFIND and RMWHERE establishes pointers to the required rows of a relation. In turn these routines call RMLOOK, RMSAV, and RMRES routines. These routines also establish pointers to selected attributes of a relation.

Integrity rule processing routines help in maintaining integrity and consistency of a database. Rules specified on attributes of relations are checked by CHKTUP routine. At any stage of execution of DBMS, rule checking flag can be assigned using RMRULE routine. PRULE routine prints out all rules assigned within a database. Rules can be specified using LODRUL routine.

Memory management routines allocate the available computer memory into a number of blocks. The system has capability to allocate 20 blocks or pages at a time. The data is first stored or retreived into these pages. If a page is used completely by a relation then another available page is allocated to the relation. If all pages are occupied then a least recently used page is replaced. The pages not modified are overwritten by a new data. BLKDEF routine defines a new block in memory. BLKEXT allocates size of a block in terms of number of rows and number of columns. BLKCHG changes the dimension of an existing block. BLKMOV moves data between arrays. GLKCLR clears a block from memory.

Command processing routines read interactive commands in a free format, check the syntax of the user commands, interpret them with reference to system conventions and store them for future use. LXLINE routine reads a new command line. LXLENC, LXGETI, LXGETR and LXGETT identify records, integer words, real words and character words in a command line respectively. LXID, LXITEM, LXGEN, and LXEND get identification of the ith item, number of items in the last command, length of a command line, and end of a command line, respectively.

Relational algebra routines perform SELECT, JOIN and PROJECT operations on relations in a database.

Routines for security and protection of a database make password checks, assign passwords and modifies them. Seperate passwords are provided for database modification access and read access. Routines used for this purpose are HASHIN, LODPAS, and RMUSER. HASHIN routine changes 8 character password into a 16 character word. LODPAS processes passwords for relations. RMUSER sets current user identification.

7.2.7 Limitations of MIDAS/R

There are a few limitations of the MIDAS/R program. One of the limitations is that program does not have capability to operate on a number of databases simultaneously. Secondly, the maximum size of a row in a relation cannot exceed 1024 words. If the size of a row exceeds this limit, user should split the row suitably and operate on portions of a row at a time. Also, the number of attributes in a relation cannot exceed 20. The memory management scheme has fixed block size. User has no control over the block size to tune it according to the relation size. At present only five relations can be operated at a time in the system buffer as only five pointers to current relations are maintained by the DBMS. Separate external data modelling facility is not available. User has to operate on the external model which is same as the internal model. This means that there is one-to-one correspondence between external model and internal model.

7.3 IMPLEMENTATION OF MIDAS/N

MIDAS/N is a database management system to support data organization of numerical computations. MIDAS/N is implemented based on numerical data model. In this section, we describe the capabilities, database organization, data definition and data manipulation commands of MIDAS/N. Also details of program architecture and limitations of the system are given.

7.3.1 Capabilities of MIDAS/N

MIDAS/N program is written in FORTRAN 77. It has data definition and data manipulation commands to define large order matrix data and manipulate them. Large matrices such as rectangular, square, upper triangular, lower triangular and hyper matrices can be defined in the database. Matrix data can be arranged in row, column, or submatrix order. Data can be short integer, long integer, real, double-precision and character types. Data mainpulation commands of MIDAS/N can store, retrieve, modify and delete matrices. Data can be accessed in row column or submatrix order. Also individual data elements of a matrix can be accessed. Database security is provided through a password access. Error recovery mechanisms are available.

7.3.2 Database of MIDAS/N

MIDAS/N has capability to create a number of databases, upto a maximum of 20 in the current implementation. These databases can be accessed simultaneously. The databases can be permanent or temporary. A database can store data of a number of matrices, upto a maximum of 20. The size of a database and a matrix is unlimited, but only depends on the availability of disk space. Databases can be organized at a number of hierarchical levels and can be accessed using a path name. Databases and matrices are identified by a unique name. Data organization of MIDAS/N is schematically shown in Figure 7.3.1.

7.3.3 Data Definition Subroutines of MIDAS/N

Data definition subroutines of MIDAS/N can be used to define databases and matrices. These are FORTRAN call statements and can be directly interfaced with an application program. These are described in the following paragraphs.

Database Definition:

```
CALL NDBDFN (NAME, PTHNAM, TYPE, STAT, IERR)
```

NAME = Name of a database

PTHNAM = Path name in database hierarchy

TYPE = Random or sequential access file type

STAT = Permanent or temporary status of a database

IERR = Error code

This subroutine can be used to define a database. Path name specifies the hierarchy of databases that are stored in a computer system file directory organized at various levels.

Renaming a Database:

CALL NDBRNM (OLDBN, NEWBN, PTHNAM, IERR)

OLDBN	=	Old database name
NEWBN	=	New database name
PTHNAM	=	Path name
IERR	=	Error code

This subroutine changes the name of a database.

Matrix Definition:

CALL NDSDFN (NAME, DSNAME, ISUB, JSUB, ORDER, NROW, NCOL, DTYPE, IERR)

NAME	=	Database name
DSNAME	=	Data set (Matrix) name
ISUB	=	Row dimension of a submatrix if present
JSUB	=	Column dimension of a submatrix if present
ORDER	=	Order of data storage (explained below)
NROW	=	Row size of the matrix
NCOL	=	Column size of the matrix
DTYPE	=	Data type of data elements in matrix
IERR	=	Error code

A matrix can be defined by calling this subroutine. Order of the matrix refers to the data storage order which can be row-wise, column-wise, or submatrix-wise. In case of a triangular matrix, order is either row-wise or column-wise. If submatrices are used, then size of a submatrix should be given.

Matrix Redefinition:

CALL NDSRDF (NAME, DSNAME, ISUB, JSUB, ORDER, NROW, NCOL, DTYPE, IERR)

This routine redefines a matrix in a different storage order. A matrix which is in either row, column or submatrix order can be redefined to any of other order (row, column, submatrix). An upper triangular matrix can be redefined to either row or column order. Similarly a lower triangular matrix can be redefined to either row or column order. Data types can be redefined as integer, real and double precision (excepts characters). Arguments are same as in matrix definition.

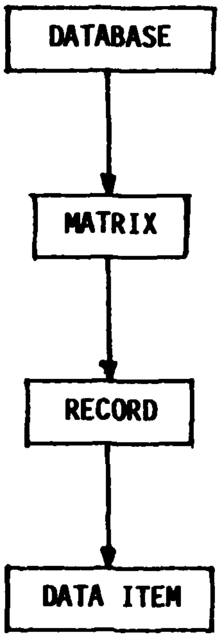


Figure 7.3.1 Logical Data Organization in MIDAS/N

Matrix Renaming:

```
CALL NDSRNM (NAME, OLDNAM, NEWNAM, IERR)

    NAME     = Name of a database

    OLDNAM   = Old name of a matrix

    NEWNAM   = New name of a matrix

    IERR     = Error code
```

This subroutine changes the name of a matrix.

7.3.4 Data Manipulation Commands

Data manipulation subroutines of MIDAS/N can be used to open, close, delete and compress a database, store, retrieve, delete and copy a matrix. The function and description of these commands are given in the following paragraphs.

Open a Database:

```
CALL NDBOPN (NAME, PTHNAM, IERR)

    NAME     = Name of a database

    PTHNAM   = Path name in database hierarchy

    IERR     = Error code
```

This subroutine can be used to open a database.

Close a Database:

```
CALL NDBEND (NAME, IERR)

    NAME     = Name of a database

    IERR     = Error code
```

This subroutine closes a database. Any modification to data in system buffer are transfered to database files.

Delete a Database:

```
CALL NDBDEL (NAME, PTHNAM, IERR)
```

This routine deletes an existing database. Arguments are same as in NDBOPN.

Compress a Database:

```
CALL NDBCMP (NAME, IERR)
```

Compresses a database. Empty spaces created due to deletion or redefinition of matrices are removed by moving data in a database. This command helps in efficient utilization of disk space.

Store a Matrix:

```
CALL NDSPUT (NAME, DSNAME, NSTR, NEND, ISTR, ORDER, UBUF, IROW,
             ICOL, IERR)
```

NSTR = Starting row or column or submatrix number for storing data

NEND = Ending row or columing or submatrix number for storing data

ISTR = Starting element number of each row or column

ORDER = Data storage order

UBUF = User buffer (array name)

IROW = Row dimension of the user buffer

ICOL = Column dimension of the user buffer

IERR = Error code

This command stores a matrix data from user buffer into a database. Full or part of a matrix can be stored and its size specified using NSTR and NEND. Row or column storage order can be used for a matrix whose order is defined as row-wise, column-wise or submatrix-wise in data definition. Submatrix storage order can only be used for a matrix defined with submatrix elements.

Retrieve a Matrix:

```
CALL NDSGET (NAME, DSNAME, NSTR, NEND, ISTR, ORDER, UBUF, IROW,
             ICOL, IERR)
```

A matrix can be retrieved into a user buffer from a database using this subroutine. Arguments are the same as defined in NDSPUT. Full or part of a matrix can be retrieved.

Retrieve a Matrix in Row Order:

```
CALL NDGETR (NAME, DSNAME, NSTR, NEND, ISTR, UBUFF, IROW, ICOL, IERR)
```

Retrieves a matrix in row order. Arguments are the same as in NDSGET.

Retrieve a Matrix in Column Order:

```
CALL NDGETC (NAME, DSNAME, NSTR, NEND, ISTR, UBUF, IROW, ICOL, IERR)
```

Retrieves a matrix in column order. Arguments are the same as in NDSGET.

Retrieve a Matrix in Submatrix Order:

```
CALL NDGETM (NAME, DSNAME, NSTR, NEND, ISTR, UBUF, IROW, ICOL, IERR)
```

Retrieves a matrix in submatrix order. Matrix must have been defined to be in submatrix order during data definition. Arguments are the same as in NDSGET.

Store a Matrix in Row Order:

```
CALL NDPUTR (NAME, DSNAME, NSTR, NEND, ISTR, UBUF, IROW, ICOL, IERR)
```

Stores a matrix in row order. Arguments are the same as in NDSPUT.

Store a Matrix in Column Order:

```
CALL NDPUTC (NAME, DSNAME, NSTR, NEND, ISTR, UBUF, IROW, ICOL, IERR)
```

Stores a matrix in column order. Arguments are the same as in NDSPUT.

Store a Matrix in Submatrix Order:

```
CALL NDPUTM (NAME, DSNAME, NSTR, NEND, ISTR, UBUF, IROW, ICOL, IERR)
```

Stores a matrix in submatrix order. Matrix should have been defined to be in submatrix order.

Copy a Matrix:

```
CALL NDSCPY (NAME1, DSNAME, NAME2, IERR)
```

NAME1 = Name of the database containing matrix data

DSNAME = Name of the datasset

NAME2 = Name of the database into which matrix has to be copied

IERR = Error code

This subroutine copies a matrix from one database to another database.

Delete a Matrix:

```
CALL NDSDEL (NAME, DSNAME, IERR)
```

IERR = Error code

Deletes a matrix from the database.

7.3.5 Matrix Operations Utilities

MIDAS/N has several routines to carry out operations on matrices stored in the database. These include matrix addition, scaling and multiplication routines. Algorithms for these utilities are developed to utilize the storage order of the data sets; i.e., if a matrix is stored in the row order in the database, an algorithm is developed to use the matrix in that order. This is done to minimize the disk I/O and thus perform the operations efficiently. The current routines in the system are described in the following. More routines will be added as need arises.

Multiply General Matrices:

```
CALL NMTPYx (NAME1, DSNAME1, NAME2, DSNAME2, NAME3, DSNAME3, IERR)
```

NMTPY1 - Computes $AB = C$

NMTPY2 - Computes $AB^T = C$

NMTPY3 - Computes $A^TB = C$

NMTPY4 - Computes $A^TB^T = C$

Add Matrices:

```
CALL NMADDx (NAME1, DSNAME1, NAME2, DSNAME2, NAME3, DSNAME3, IERR)
```

NMADD1 - Computes $A + B = C$

NMADD2 - Computes $A + B^T = C$

NMADD3 - Computes $A^T + B = C$

NMADD4 - Computes $A^T + B^T = C$

Subtract Matrices:

```
CALL NMSUBx (NAME1, DSNAME1, NAME2, DSNAME2, NAME3, DSNAME3, IERR)
```

NMSUB1 - Computes $A - B = C$

NMSUB2 - Computes $A - B^T = C$

NMSUB3 - Computes $A^T - B = C$

NMSUB4 - Computes $A^T - B^T = C$

Scale a Matrix:

```
CALL NMSCLx (NAME1, DSNAME1, NAME2, DSNAME2, SCALE, IERR)
```

NMSCL1 - Computes $A*SCALE = C$

NMSCL2 - Computes $A^T*SCALE = C$

Transpose of a Matrix:

CALL NMTRPZ (NAME1, DSNAME1, NAME2, DSNAME2, IERR)

Computes $A^T = C$

Multiply a Matrix by a Diagonal Matrix:

CALL NMTDGx (NAME1, DSNAME1, NAME2, DSNAME2, ARRAY, IERR)

NMTDG1 - Computes ARRAY*A = C

NMTDG2 - Computes ARRAY*A^T

NMTDG3 - Comptes A*ARRAY = C

NMTDG4 - Computes A^T*ARRAY = C

Rearrange Rows/Columns of a Matrix:

CALL NMSRTx (NAME1, DSNAME1, NAME2, DSNAME2, ARRAY, IERR)

NMSRT1 - Rearranges rows according to the order specified in ARRAY

NMSRT2 - Rearranges columns according to the order specified in ARRAY

7.3.6 Equation Solvers and Matrix Decomposition Routines

MIDAS/N has several routines to decompose and solve a linear system of equations. The coefficient matrix may be stored in skyline or banded form. It may also be a genral matrix. In the following, these routines are described. Other equation solvers and eigenvalue extractors will be added at a later date.

Decompose a symmetric matrix by skyline method.

CALL NMSKY1 (NAME1, DSNAME1, NAME2, DSNAME2, NEQ, MAXCOL, IER)

NAME1 = Database name containing the coefficient matrix

DSNAME1 = Data set name containing the coefficient matrix stored in one dimensional form: the decomposed coefficient matrix is also stored under this name.

NAME2 = Database name containing the addresses of the diagonal elements of the coefficient matrix

DSNAME2 = Data set name containing the addresses of the diagonal elements of the coefficient matrix

NEQ = Size of the coefficient matrix

MAXCOL = Maximum column height of the coefficient matrix

IER = Frror parameter

Perform backward and forward substitutions to solve the decomposed system of linear equation by the skyline method.

```
CALL NMSKY2 (NAME1, DSNAME1, NAME2, DSNAME2, NAME3, DSNAME3, NEQ,
            MAXCOL, IER)
```

NAME1 = Database name containing the decomposed coefficient matrix

DSNAME1 = Data set name containing the decomposed coefficient matrix stored in one dimensional form

NAME2 = Database name containing the addresses of diagonal elements of coefficient matrix

DSNAME2 = Data set name containing the addresses of diagonal elements of coefficient matrix

NAME3 = Database name containing the R.H.S. vector at entry and solution vector on return

DSNAME3 = Data set name containing the R.H.S. vector at entry and solution vector on return.

NEQ = Size of the coefficient matrix

MAXCOL = Maximum column height of the coefficient matrix

IER = Error parameter

Solve a system of linear equations by the skyline method.

```
CALL NMSKY3 (NAME1, DSNAME1, NAME2, DSNAME2, NAME3, DSNAME3, NEQ,
            MAXCOL, IER)
```

NAME1 = Database name containing the coefficient matrix stored in one dimensional form

DSNAME1 = Data set name containing the coefficient matrix stored in one dimensional form at entry, and decomposed coefficient matrix on return

NAME2 = Database name containing the addresses of diagonal elements of coefficient matrix

DSNAME2 = Data set name containing the addresses of diagonal elements of the coefficient matrix

NAME3 = Database name containing R.H.S. vector at entry and solution vector on return

DSNAME3 = Data set name containing R.H.S. vector at entry and solution vector on return

NEQ = Number of equations

MAXCOL = Maximum column height of coefficient matrix

IER = Error parameter

Decompose a symmetric banded matrix by Cholesky's method.

CALL NMBND1 (NAME1, DSNAME1, NEQ, MBND, IER)

NAME1 = Database name containing coefficient matrix at entry and decomposed coefficient matrix on return

DSNAME1 = Data set name containing the coefficient matrix at entry and decomposed coefficient matrix on return

NEQ = Size of the coefficient matrix

MBND = Half bandwidth of the coefficient matrix

IER = Error parameter

Note: The coefficient matrix is banded and is stored in a squeezed form.

Performs backward and forward substitutions to solve decomposed system of linear banded equations.

CALL NMBND2 (NAME1, DSNAME1, NAME2, DSNAME2, NEQ, MBND, IER)

NAME1 = Database name containing decomposed coefficient matrix

DSNAME1 = Data set name containing decomposed coefficient matrix

NAME2 = Database name containing R.H.S. vector at entry and solution vector on return

DSNAME2 = Data set name containing R.H.S. vector at entry and solution vector on return

NEQ = Size of coefficient matrix

IER = The decomposed matrix is stored in a squeezed form

Note: The decomposed matrix is stored in a squeezed form.

Solve system of linear banded equation by Cholesky's method.

CALL NMBAND3 (NAME1, DSNAME1, NAME2, DSNAME2, NEQ, MBND, IER)

NAME1 = Database name containing the coefficient matrix at entry and decomposed matrix on return

DSNAME1 = Data set name containing the coefficient matrix at entry and decomposed matrix on return

NAME2 = Database name containing the R.H.S. vector at entry and solution vector on return.

DSNAME2 = Data set name containing the R.H.S. vector at entry and solution vector on return

NEQ = size of the coefficient matrix

MBND = Half bandwidth of the coefficient matrix

IER = Error parameter

Decompose a general full matrix.

CALL NMGSL1 (NAME1, DSNAME1, NEQ, IER)

NAME1 = Database name containing the coefficient matrix at entry and decomposed matrix on return

DSNAME1 = Data set name containing the coefficient matrix at entry and decomposed matrix on return

NEQ = Size of the coefficient matrix

IER = Error parameter

Perform backward and forward substitutions to solve a decomposed general system of equations.

CALL NMGSL2 (NAME1, DSNAME1, NAME2, DSNAME2, NEQ, IER)

NAME = Database name containing the decomposed coefficient matrix

DSNAME1 = Data set name containing the decomposed coefficient matrix

NAME2 = Database name containing the R.H.S. vector at entry and solution vector on return

DSNAME2 = Data set name containing the R.H.S. vector at entry and solution vector on return

NEQ = Size of coefficient matrix

IER = Error parameter

Solve system of linear equations.

```
CALL NMGSL3 (NAME1, DSNAME1, NAME2, DSNAME2, NEQ, IER)
```

NAME1 = Database name containing the coefficient matrix at entry and decomposed matrix on return

DSNAME1 = Data set name containing the coefficient matrix at entry and decomposed matrix on return

NAME2 = Database name containing the R.H.S. vector at entry and solution vector on return

DSNAME2 = Data set name containing the R.H.S. vector at entry and solution vector on return

NEQ = Size of coefficient matrix

IER = Error parameter

Decompose a full symmetric matrix by modified Choleshy's method.

```
CALL NMSYM1 (NAME1, DSNAME1, NEQ, IER)
```

NAME1 = Database name containing the coefficient matrix at entry and decomposed matrix on return

DSNAME1 = Data set name continaing the coefficient matrix at entry and decomposed matrix on return

NEQ = Size of coefficient matrix

IER = Error parameter

Perform backward and forward substitution to solve a decomposed symmetric system of linear equations.

```
CALL NMSYM2 (NAME1, DSNAME1, NAME2, DSNAME2, NEQ, IER)
```

NAME1 = Database name containing the decomposed coeffcient matrix

DSNAME1 = Data set name containing the decomposed coefficient matrix

NAME2 = Database name containing R.H.S. vector at entry and solution vector on return

DSNAME2 = Data set name containing R.H.S. vector at entry and solution vector on return

NEQ = Size of the coefficient matrix

IER = Error parameter

Solve a full symmetric system of linear equations by the modified Cholsky's method.

CALL NMSYM3 (NAME1, DSNAME1, NAME2, DSNAME2, NEQ, IER)

NAME1 = Database name containing the coefficient matrix, at entry and decomposed matrix on return

DSNAME1 = Data set name containing the coefficient matrix at entry and decomposed matrix on return

NAME2 = Database name containing R.H.S. vector, at entry and solution vector on return

DSNAME2 = Data set name containing R.H.S. vector at entry and solution vector on return

NEQ = Size of coefficient matrix

IER = Error parameter

7.3.7 Program Details

MIDAS/N is written in FORTRAN 77. Subroutines of the program can be grouped into (i) file definition routines, (ii) input-output routines, (iii) addressing routines, and (iv) memory management routines. A brief description of these routines is given in the following paragraphs.

File definition routines open a file unit and assign database name to be the file name. An available logical unit number is assigned to the file. Routine NDBDFN performs this function. File status and file types are assigned according to user request. File organization is shown in Figure 7.3.2.

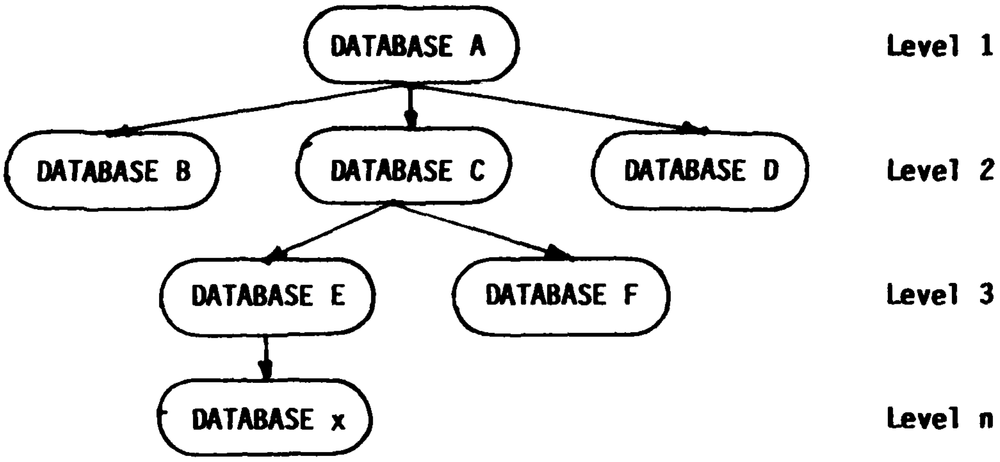
Input-output routines perform data storage and retrieval operation. NDSPUT, NDSGET, IN$MEM, IN$DST, D$ASIN, D$READ and D$WRITE routines do input-output operations. These routine transfer data from user buffer to system buffer and vice-versa. Also these routines check the matrix order, data type and matrix size and prints out error message if data manipulation operations are not valid.

Addressing routines IN$MEM and IN$DST allocate physical storage location address to matrices created in the database. The system maintains an index table to provide address of stored records. Index table provides a pointer to data defintion block which contains details of a matrix such as name, type, order, size. Data definition block is also stored at the beginning of actual data in a file. Matrix data is mapped on to physical storage space in a linear address sequence. Smallest physical data item correspond to one word length. The physical storage structure is schematically shown in Figure 7.3.3.

Memory management routines G$PAGE, R$MVPG and P$EXST allocate pages in the memory to various matrices. The scheme uses fixed number of pages of same size. The paging memory is an array in the common block MCONTNT of short integer variable. FORTRAN equivalence statement is provided to deal with other data types. The memory management scheme uses 'Least Recently Used' page replacement algorithm. A counter is maintained for each page. When a page is to be replaced the page having highest counter value becomes the candidate. Page replacement is done when no free pages are available. Page not modified is overwritten instead of replacement.

7.3.8 Limitations of the MIDAS/N

There are a few limitations in the system. Matrix size remains fixed after it is defined. Any alteration in matrix size requires data transfer to a new physical storage location. At present maximum of 20 matrices can be defined in a database. However this number can be increased by changing certain parametes in the program. The system does not support external data modelling facility. Thus, application program view of database is tied to the internal data model.



Path name to database F ≡ A > C > F

Figure 7.3.2 Hierarchical Level of Database Organization

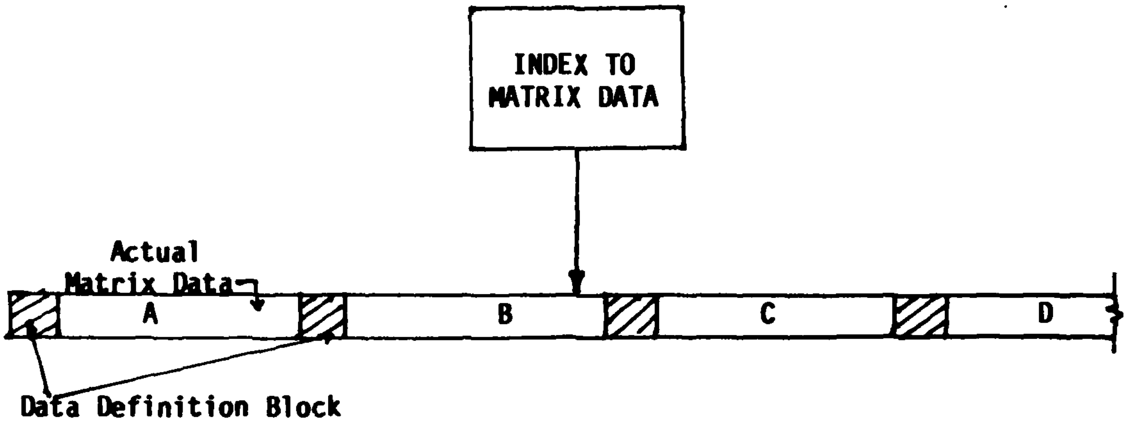


Figure 7.3.3 Physical Storage Structure

8. DISCUSSION AND CONCLUSIONS

Programs for structural analysis and design of practical systems are quite complex. Data needed or generated to accomplish the task is enormous. If proper data handling facilities and/or proper databases are not used, the software can have only limited capability. Its maintenance and expansion can be very difficult or even impossible. Development of a software for analysis and design of complex systems is an evolutionary process. The system is usually written for a class of applications. It is then expanded by adding new features and capabilities to meet user's demands. This type of program evolution requires a well designed database and its management. The database management system (DBMS) must be highly sophisticated and intelligent (user friendly). The DBMS should not be a stumbling block in the range of applications a designer may be interested in. Rather, it should facilitate various applications. Such a database management system is described in the report. The system is called MIDAS which stands for **M**anagement of Information for **D**esign and **A**nalysis of **S**ystems. The system has capabilities that will be highly useful in analysis and design of systems. To evaluate the system, a database for analysis and design optimization of complex structural systems is developed. A procedure for design of such a database is described and used. To properly design the database, two existing and commercially available programs for analysis of complex systems are studied. These are ADINA and GIFTS which are the state-of-the-art programs. Their databases are quite extensive. These databases are studied in detail and documented. Based on the study and the procedures discussed, a design of the database for analysis and design of complex structural systems is presented. The capabilities considered are linear, nonlinear, static and dynamic analysis. The structure can be modeled using substructures. Thermal and acceleration loads are included in the design process.

The proposed database design is considered as preliminary. In the near future, it will be implemented and evaluated using MIDAS. A class of optimum design problems will be solved using the database and its management system. Based on the study, a final design of the database can be determined.

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